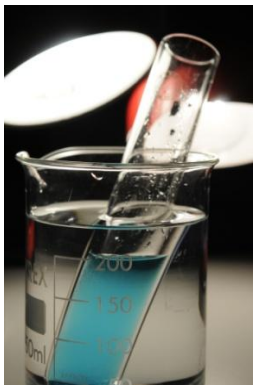
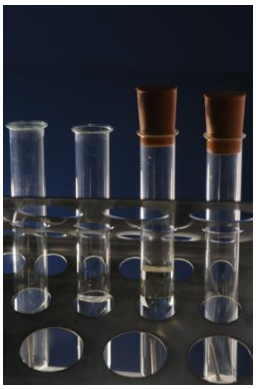
Getting Practical

# Reflecting on Practical Work



centre for science education

**Getting Practical: Improving Practical Work in Science**

**Introduction**

*'Science without practical is like swimming without water'* (SCORE, 2008)

The vast majority of science teachers will empathise with this comment. Practical work is an integral component of science teaching. However, defining the real value and purpose of practical work poses a difficult set of questions and divides opinion across the science education profession. We know that we want to do practical work, and we feel strongly that it must be part of science teaching, but we are not always sure why, what its benefits are or how to get the most from it.

The activities described in this book aim to address these issues. They help teachers to take stock of the practical work they do, by considering its key aims and objectives and evaluating its effectiveness.

This is not a compendium of new practical activities, nor a recommendation of equipment and techniques. Instead, the aim is to help teachers reflect on their use of practical work and to consider how small changes in its staging can make it more effective.

Three key sources were used to provide the background, content and structure for this project:

- Robin Millar's (University of York) research on the role of practical work in the teaching and learning of science
- A report, following a series of questionnaires and interviews with educators, published by the Science Community Representing Education (SCORE) in 2008 entitled *Practical Work in Science: A report and proposal for a strategic framework*
- A self-study pack produced by the National Strategies (*Interactive Practicals*), designed to help teachers review and improve their delivery of practical work

Full details of these sources are given in the Recommended Reading.

The activities described here underpin the first sessions of the Getting Practical Continuing Professional Development (CPD) package, which is delivered by the national network of Science Learning Centres. The later sessions in the CPD package look at how practical work is staged in the classroom, developing effective approaches to practical work and exploring resources.

**What is Practical Work?**

Most science lessons involve a range of teaching strategies, some of which come under the umbrella of *practical work*.

The nucleus of practical work relates to pupils' interactions with objects, in order to observe and develop their understanding of the natural world. It encompasses laboratory procedures and techniques, investigations and fieldwork. Some teachers may feel that its definition goes further, to include activities such as analysis of secondary data, computer simulations, modelling and role-play, discussion generated from observations, or carrying out surveys (SCORE, 2008).

The following definitions of practical work underpin the activities described in this book:

> *'Any science teaching and learning activity which at some point involves the students, working individually or in small groups, in observing or manipulating objects to develop understanding'*
>
> Millar (2009)

> *'Any activity that enables pupils to have direct, often hands-on, experience of the phenomena they are studying'*
>
> The National Strategies (2008)

An interesting point to consider here is whether teacher demonstration falls within these definitions. However, whether it does or not, the principles of practical work apply to both pupil and teacher-led activity; the key issue is to make it *effective*.

**What is the Purpose of Practical Work?**

Practical work is often described as 'hands-on' activity but this is a limiting description. Its over-arching principle is to make links between the concrete and abstract worlds.

Tiberghien (2001) and Millar and Abrahams (2008) describe this as a link between two domains of knowledge: that of observables and that of ideas (Figure 1). Pupils therefore need to be engaged in the scientific ideas behind the practical work they are carrying out, whether these are about the


**Figure 1: Practical work enables pupils to make links between the domains of observables and ideas**

concepts they are investigating or about approaches to enquiry.

This gives rise to a compelling mantra for practical work: *hands-on, minds-on.*

**Getting Practical Mapping Activities**

The activities described here allow teachers to map their practical work, reflecting on its aims and objectives and assessing its effectiveness. This mapping of practical work could be made on any learning episode; a lesson may have a series of learning episodes within it or the learning episode may extend over a series of lessons.

**Activity 1: Exploring the reasons for doing practical work**

In the first activity, teachers think about a range of practical tasks and make a note of a couple of reasons why they would do each one (Figure 2). They then consider whether the resulting wide range of reasons can be grouped into categories. Table 1 shows some sample results.


**Figure 2: What is the purpose of this practical activity?**

| Group 1 | Group 2 | Group 3 | Group 4 |
|---|---|---|---|
| • introducing a concept<br>• developing understanding of a concept<br>• raising awareness of a real science issue<br>• demonstrating a scientific idea<br>• challenging misconceptions | • gaining experience in use of equipment<br>• basic skill to allow other practicals to be done without having to explain it all again<br>• learning to set up equipment correctly<br>• careful use of equipment | • making and testing hypotheses<br>• developing planning skills<br>• constructing graphs and lines of best fit<br>• recording results clearly<br>• using equipment safely<br>• developing fair testing skills | • fun and engaging<br>• making a simple idea exciting<br>• making the science relevant to everyday experience<br>• experiencing a regular exam question |

**Table 1: Exploring the reasons for doing practical work**

There will of course be variation in the groupings which each teacher chooses but this activity tends to reveal three main purposes (Figure 3):

A. to develop scientific knowledge and understanding

B. to teach skills in carrying out a practical technique or selecting and using scientific equipment

C. to develop understanding of scientific enquiry

These categories are explored further below and in Millar (2010).

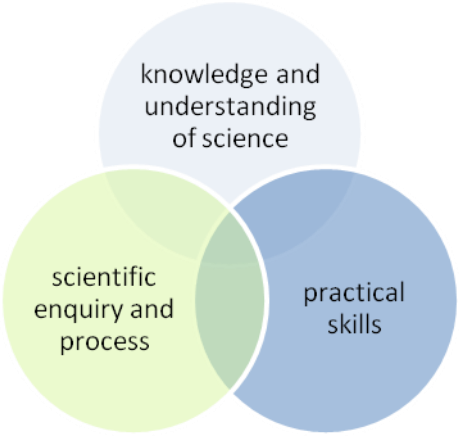



**Figure 3: Three main purposes for practical work**

Many teachers include additional reasons which fall outside these three categories, such as those given in group 4 (Table 1) which reflect the motivational aspects or 'awe and wonder' of practical work. While these are of course important objectives, they are not (or ought not to be) the sole reasons for planning or carrying out an activity. Indeed, it would be inconceivable to set the converse objectives, which would be to disengage or de-motivate pupils; should not every teaching and learning activity engage, motivate and inspire?

**Activity 2: Identifying the key learning outcomes of a range of practical activities**

In order to explore the reasons for doing practical work in more depth, the three categories described above were expanded into the categories shown in Figure 4 (Millar, 2008).

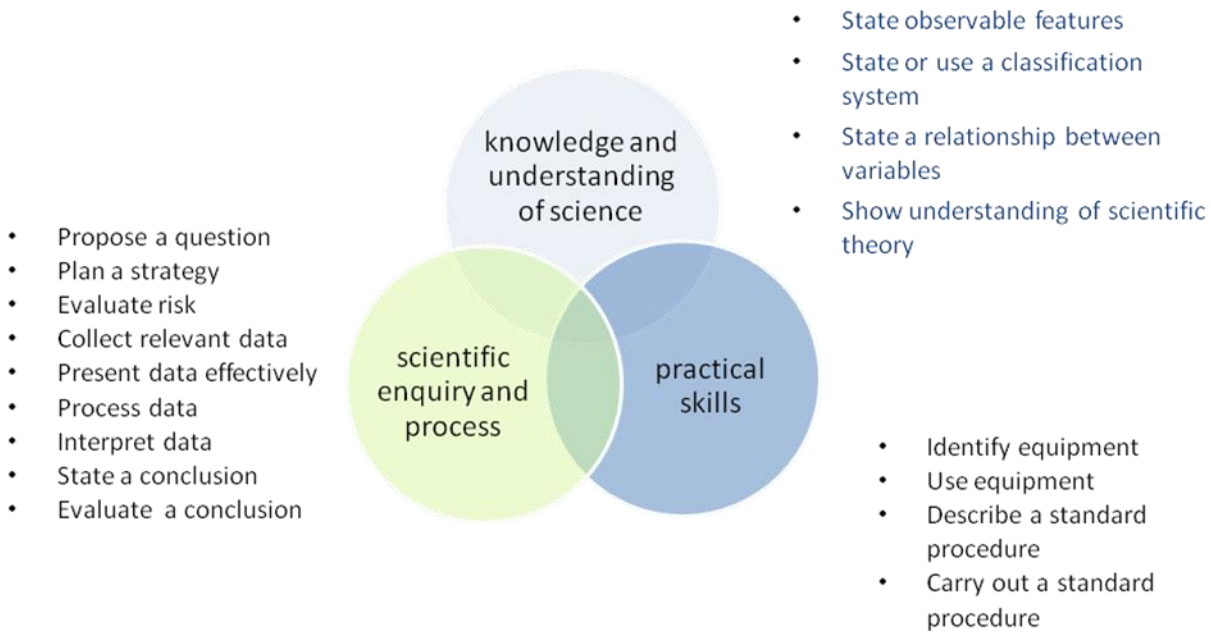



Figure 4: Expanding the three categories of reasons for practical

The audit tool (Figure 5) enables teachers to think about the main purposes of a range of practical activities. Practical work, unlike many other teaching and learning approaches, does not always have a rigorous application of objective setting; it tends to be done simply because it's practical work and therefore 'part and parcel' of science teaching. This audit enables teachers to focus on what they want to achieve through their practical work.

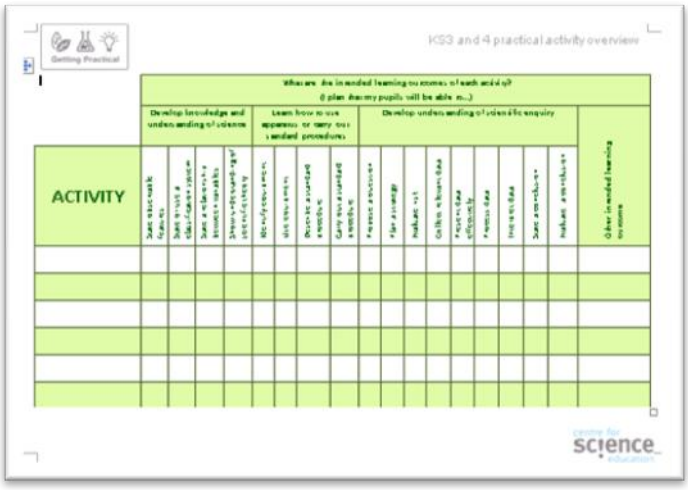



Figure 5: Audit tool for a range of practical activities

Teachers start by looking at five or six practicals which they have recently carried out and use the statements on the audit tool (Figure 5) to identify the purpose of each. The statements are grouped according to the categories described above.

This provides an opportunity for teachers to consider some key questions about their use of practical work. For example:

- how many intended learning outcomes are they aiming to achieve through a practical activity?
- is a particular practical always used to achieve the same intended learning outcomes?
- how should the range of intended learning outcomes look for an individual pupil within a topic/year/key stage?

Following trials of the audit a tendency for teachers to tick a large number of intended learning outcomes for any particular activity was observed. In part, this is due to a desire to 'do the right thing' as teachers try to fit their practical work to the categories given to them. However, it raises an important question for all teachers to address: is it possible to successfully work towards more than two or three learning outcomes for any classroom activity? It may be over-ambitious to expect pupils to plan a practical investigation, gather evidence, present, analyse and evaluate it, all in the course of a single learning episode. Teachers will find that by focussing on just one or two learning outcomes (for example through giving out a set of instructions so that pupils can concentrate on collecting data), the effectiveness of the practical is significantly improved.

All teachers have a core set of favourite, reliable practical activities which they repeat year after year. These activities are often built into lessons with little consideration for pupils' prior experiences or skills development. Using this audit tool has enabled teachers to review how they use these favourite practicals, and to consider whether they can be 'tweaked' to ensure that different outcomes are met for different classes or different pupils in the same class. These ideas about *staging for effectiveness* are followed up in Activity 3 and in the full 'Getting Practical' CPD package.

It has also become clear through carrying out this audit, that, within departmental schemes of work, there are often gaps in the range of learning outcomes which are tackled through practical work, or that there is a bias towards one group of outcomes over another. Some departments may find that they focus heavily on enquiry skills, but rarely use practical work to develop conceptual understanding. A review of practical work allows the department to build a core set of practical work within a topic, year or Key Stage which enables pupils to explore and develop their key skills,

knowledge and understanding *through* practical work. This embeds practical work as a significant part of learning, and not just a fun and engaging add-on.

It can be seen that this audit of practical work raises a number of discussion points relating to the intended learning outcomes selected for any particular activity. The importance of this is to reflect on why each practical is done in the classroom. In many cases, this simple thought process is enough for teachers to start taking steps towards improving the effectiveness of their practical work, whether this is through prioritising or clarifying the learning outcomes, by ensuring that pupils are able to develop a range of skills, or by applying different learning outcomes to better meet pupils' needs.

The case studies included in this booklet describe how teachers explore some of these ideas in depth.

| Getting Practical | What are the intended learning outcomes of each activity? (I plan that my pupils will be able to…) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Develop knowledge and understanding of science | | | | Learn how to use apparatus or carry out standard procedures | | | | Develop understanding of scientific enquiry | | | | | | | | | Other intended learning outcome |
| **ACTIVITY** | State observable features | State or use a classification system | State a relationship between variables | Show understanding of scientific theory | Identify equipment | Use equipment | Describe a standard procedure | Carry out a standard procedure | Propose a question | Plan a strategy | Evaluate risk | Collect relevant data | Present data effectively | Process data | Interpret data | State a conclusion | Evaluate a conclusion | |
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## Audit tool for a range of practical activities

**Activity 3: Reflecting on the effectiveness of practical work**

Teachers are often highly effective at managing the 'hands-on' activity in their lessons, but are they always as effective when trying to engaging pupils' minds? Recent research suggests not (Abrahams and Millar, 2008).

However, by considering the steps taken when practical work is planned and delivered its effectiveness can be evaluated (Millar, 2010). Figure 6 illustrates a framework for assessing effectiveness of practical work.

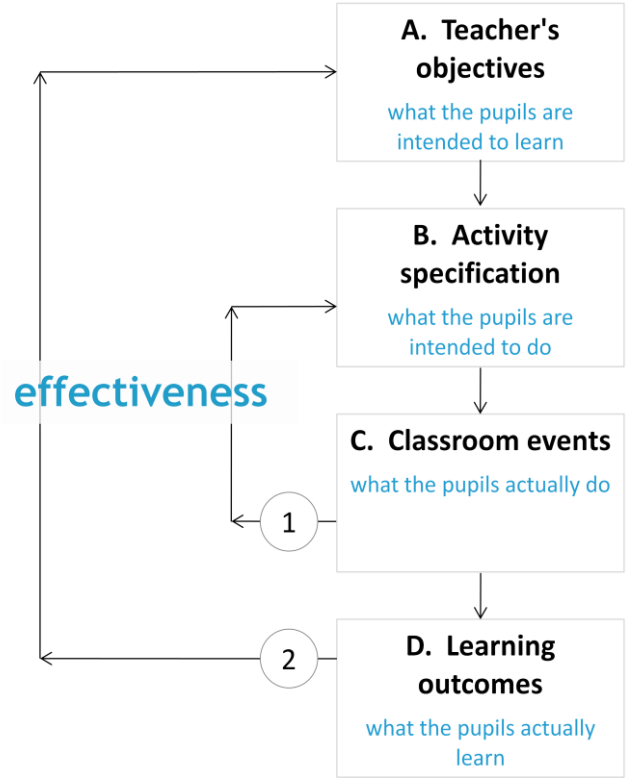



**Figure 6: The steps taken when practical work is planned, delivered and evaluated**

The starting point in planning should be the identification of *objective(s)* which state what the teacher wants the pupils to learn from the activity (box A).

Once the objective is defined the activity is planned and a series of tasks set for the pupils. The tasks may be structured or open-ended, but the teacher will have an expectation of what the pupils will do in the activity in order to achieve the objectives (box B).

The first stage of assessing effectiveness can therefore take place when the activity is carried out in the classroom. Teachers monitor what the pupils do and use appropriate interventions to direct them. An assessment of effectiveness can be made at this point, based on whether the pupils have carried out what was intended (box C). This is *effectiveness level 1*.

On completion of the activity, a judgement is made about pupils' achievement of the learning outcomes: have they learnt (and can recall or demonstrate understanding of) the things they were meant to learn? This second, and crucial, measure of effectiveness is *effectiveness level 2* (box D).

To help teachers to consider effectiveness at level 2, a reflective tool was developed (Figure 6) which provides a more detailed look at individual practical activities.

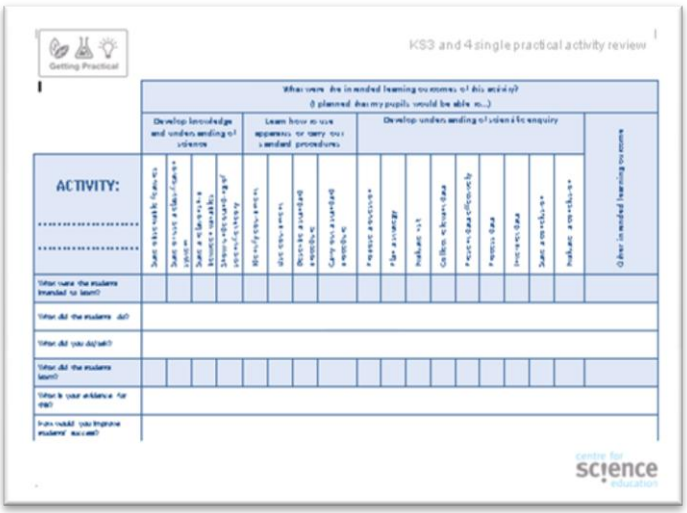



**Figure 6: Reflective tool for an individual practical activity**

The reflective tool prompts teachers to consider whether or not a particular practical achieved what was intended at effectiveness levels 1 and 2, to consider what evidence they have for this, and to think about how the practical could be made more effective.

In feedback from this process of reflection, three key discussion points have emerged:

- what evidence do teachers have for a successful practical?
- what are the features of a 'less successful' practical?
- what improvements could teachers make to improve the success of any particular practical?

For the first discussion point, it is important to consider that there is more to an effective practical than pupils having done what was intended of them (as in effectiveness level 1) and thereby having

the ‘right’ answers written in their books. Effectiveness at level 2 may more challenging to assess, but other evidence could be gathered to help. Suggestions include:

- teacher questioning
- pupil-pupil discussion or questioning lesson observations
- test or quiz answers
- pupil presentations, videos or podcasts
- open-ended written work
- pupil questionnaires
- applying knowledge from the practical in new situations

Teachers have found that, where appropriate, moving pupils away from the traditional process of 'complete the results table, plot the graph, write the conclusion' not only makes it easier to judge effectiveness, but often has the added advantage of improving pupil engagement.

In discussion of the second point (*what are the key features of a ‘less successful’ practical?*), some interesting additional questions have emerged. While most of these are linked to the planning and staging of the practical, some also refer to teachers’ interventions in the classroom (Table 2).

| Planning and staging of the practical | Teachers’ interventions in the classroom |
|---|---|
| • was the intended learning outcome appropriate for that class?<br>• were there too many intended learning outcomes?<br>• did practical technicalities distract from the learning?<br>• was the practical too open-ended or, conversely, too structured?<br>• did the pupils understand what they were supposed to be doing?<br>• was the practical clearly linked to previous knowledge?<br>• did the pupils already know what was supposed to happen? | • did the teacher ensure pupils were kept on task throughout?<br>• how did the teacher deal with unexpected results?<br>• is it wrong for a lesson to go in an unexpected direction?<br>• were the pupils learning even though the lesson was going in an unexpected direction?<br>• did unexpected classroom or time management issues occur? |

| |
|---|
| • was the practical rehearsed before the lesson? |

**Table 2: What are key features of a 'less successful' practical?**

Not surprisingly, careful planning is the key to successful practical work. As with all teaching and learning strategies, this requires clear learning objectives and appropriate instructions to pupils. Particular to practical work is also the issue of rehearsal, or trying out the activity before the lesson.

Finally, in response to the last discussion point, Table 3 shows some of the suggestions which have been made.

| Teacher-related improvements | Pupil-related improvements |
|---|---|
| • tackle fewer learning outcomes<br>• use photos as instructions rather than words<br>• use verbal rather than written instructions<br>• link more clearly to prior learning<br>• make more explicit links to real life<br>• use simpler terminology<br>• demonstrate the activity rather use a whole class practical<br>• choose a different practical! | • record observations with photos/video<br>• allow pupils more choice in what they investigate<br>• conversely, allow pupils less choice in what they investigate<br>• use less tricky practical techniques<br>• use a writing frame |

**Table 3: What improvements could teachers make to improve the success of any particular practical?**

It can be seen that the ways of improving the effectiveness of a practical can be divided into teacher and pupil actions. It is also interesting to consider whether each relates to the improvement of effectiveness at level 1 or level 2. Again, it can be seen that all these improvements link to careful planning and delivery of the practical activity.

**Summary**

Throughout these activities, some simple messages emerge. In order to get the most from any piece of practical work, teachers must ensure that they have clear learning objectives, that they can explain what their pupils need to do, and that they can assess how effective they have been, not

only at the 'hands-on' level but also the 'minds-on'. By working towards these goals, practical work becomes an integral part of learning.

| Getting Practical | What were the intended learning outcomes of this activity? (I planned that my pupils would be able to…) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Develop knowledge and understanding of science | | | | Learn how to use apparatus or carry out standard procedures | | | | Develop understanding of scientific enquiry | | | | | | | | | Other intended learning outcome |
| **ACTIVITY:** ..... ..... | State observable features | State or use a classification system | State a relationship between variables | Show understanding of scientific theory | Identify equipment | Use equipment | Describe a standard procedure | Carry out a standard procedure | Propose a question | Plan a strategy | Evaluate risk | Collect relevant data | Present data effectively | Process data | Interpret data | State a conclusion | Evaluate a conclusion | |
| **What were the pupils intended to learn?** | | | | | | | | | | | | | | | | | | |
| **What did the pupils do?** | | | | | | | | | | | | | | | | | | |
| **What did you do/ask?** | | | | | | | | | | | | | | | | | | |
| **What did the pupils learn?** | | | | | | | | | | | | | | | | | | |
| **What is your evidence for this?** | | | | | | | | | | | | | | | | | | |
| **How would you improve pupils' success?** | | | | | | | | | | | | | | | | | | |

**Reflective tool for an individual practical activity**

**Case studies: Introduction**

The case studies described here are the result of a series of workshops held with teachers as part of the development of the Getting Practical mapping activities. The teachers involved explored the key research which forms the foundation of Getting Practical and developed the content and use of the audit and reflective tools. They considered how best to use the tools and what their impacts might be on classroom practice.

Following the workshops, the teachers took the tools back into their schools to share with their colleagues and further develop their use. A few weeks after the final workshop, they were asked to report back on the impact of the audit and review tools on their practice, and these reports were developed into the following case studies

The case studies were drawn from a wide range of secondary teachers, from newly qualified to advanced skills teachers, who came from across the spectrum of secondary schools, including inner-city schools in challenging circumstances and high-achieving specialist science colleges. They describe a number of approaches to the use of the audit and review tools, and some interesting (and sometimes unexpected) outcomes.

For example, one teacher asked his pupils their opinions of the effectiveness of a particular practical, and found that they were able to identify that they had enjoyed the practical without learning anything from it! This led to a move away from doing practical work 'for the sake of it' and into more careful planning and staging so that pupils achieved 'minds-on' outcomes as well as 'hands-on'. Another teacher realised that he did not need to plan separate practical and theory lessons; by teaching the theory *through* the practical work, his pupils learned both more effectively and more efficiently.

Some teachers worked with their department to audit their use of practical work across schemes of work. This led to identification of gaps in their planning, and a chance to balance the learning achieved through practical work. Others worked with initial teacher trainees, who found that the review tools enhanced their reflections on their lessons and could be used to improve the staging of practical work for greater effectiveness.

All of the teachers involved found that their attitude towards practical work had changed, and that they developed a conception of it as a key learning strategy, not as add on activity.

**Hands-on, minds-on**

Stuart is a teacher who uses a lot of practical work in lessons, in a department that values practical work as a motivational and engaging part of science education. Practical activities are numerous and embedded in the department's schemes of work, particularly at Key Stage 3.

Stuart is the KS3 science co-ordinator of this successful science specialist college situated on the outskirts of a large city. With GCSE results well above the national average and science exceeding other subject areas, this is a thriving department that values practical work highly.

Stuart is clear about his definition of practical work: pupils being engaged in 'hands-on' activities with science apparatus. He is seen as a model of good practice within the department.

Stuart's use of the audit tool has helped him to become more self-reflective. Categorising typical practicals led Stuart to realise that often his practical activities fell into one category: 'Learn how to use apparatus or carry out procedures'. He felt that he often did practical work 'because it was on the scheme of work'. This is illustrated by his approach to the Key Stage 3 activity *Making copper sulphate*, which is written into the scheme of work and therefore always done with classes. Stuart, and indeed his pupils, would be satisfied if they had completed the procedure and made a crystal. This illustrates effectiveness level 1. Stuart has not considered what the pupils might learn from this practical - it is all about the 'doing'.

Stuart used a *rates of reaction* lesson to test the ideas developed through his use of the audit tools. In the past, he would have given pupils pre-determined concentrations of acid for them to follow a recipe-style approach. Reflection led him to use more interesting reagents (potassium manganate (VII) solution and rhubarb) but, more importantly, allowed him to set the practical in the context of stain removal. This made the activity more investigative and open ended, and shifted the objectives from skills to a scientific enquiry. The same task, presented differently, allowed access to effectiveness level 2.

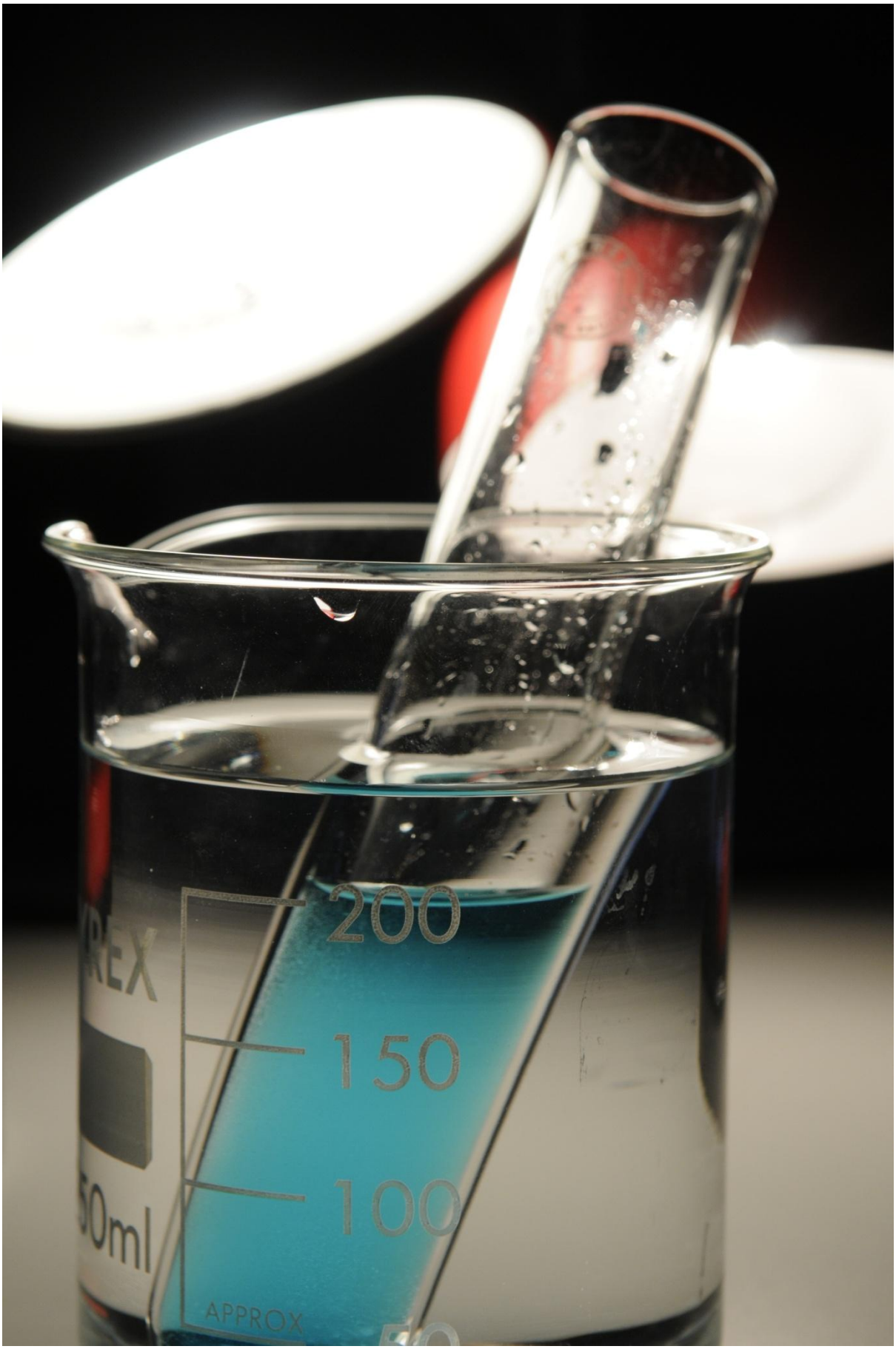
Stuart recognised that when considering an individual practical activity he found himself ticking multiple possible learning outcomes as 'these are what the practical covers', and this made him realise that, to improve effectiveness, it is important to be more selective. For example, where he might previously have asked pupils to spend a significant amount of time drawing a graph (a skill which they already have) he found that by missing that stage out and *giving* them the graph, he was able to spend more time *interpreting the data*, a skill that pupils are often less good at.

With a clear objective, pupils learning can be evaluated - this is effectiveness level 2.

Stuart has also encouraged his pupils to consider for themselves the effectiveness and value of practical work. Following a lesson on the extraction of DNA from a kiwi fruit, the pupils themselves asked what the point was, despite having completed and enjoyed the task! Stuart questioned whether the task had helped the pupils to better understand the structure or function of DNA, or whether any investigative skills had been developed. He concluded that he could improve the effectiveness of the activity by using it as a stimulating context for the development of a routine procedure such as filtration. This would have the additional benefit of making an apparently mundane procedure relevant and engaging.

Stuart summarises the audit process as 'making the purpose and execution of practical work more efficient and, therefore, more effective, by focussing on the intended learning outcomes.

This has required a significant shift in both thinking and planning, but has in Stuart's words "taken my teaching forward".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APPROX

**Understanding science concepts through practical work**

This school has a vibrant approach to teaching science in a demanding environment. Within the department practical work is regarded by the teachers as 'part and parcel' of teaching science, but without too much thought applied to this reasoning.

In a socially disadvantaged area of a large city, this school faces many challenges. It has good science facilities and a positive outlook on learning. Achievement in science at GCSE is high in comparison to other subjects but still below national averages.

As a recently qualified teacher, Matt has developed his approach to practical work through previous experience in biological sciences research, and his teacher training course, but mainly from published schemes. He noted that his colleagues often deviate from the schemes to achieve desired lesson objectives, but in the early stages of his teaching career feels he needs more experience before being confident to apply such selectivity. Discussion within his department about practical work has been limited to the level of which experiments 'worked', but with no justification of this qualification; there was an automated approach to practical work without a real consideration to its value or purpose.

Within the first level of effectiveness Matt regards his practical to be effective; generally the pupils work on task and achieve what he plans for them. However he feels that learning objectives are not always met.

Before making use of the audit tools, Matt felt his practical work was prescriptive and, though valuable, a less important element of his lessons than the theory. He sees saw time as a major factor against increasing the amount of practical work, feeling that additional lesson time would be needed to cover both the practical and conceptual aspects of each topic.

Using the audit tool enabled Matt to think clearly about the purpose of practical work, which has changed his approach. Being clear about the purpose of a practical activity has enabled him to be newly confident in selecting and modifying practicals to meet the objective of the lesson. For example in a topic called *Speeding Up,* the planned practical activities were based on measuring the speed of objects in the laboratory: a trolley on a ramp, a falling object, a walking student etc. He found that pupils were confused by the difficulty of taking the measurements, particularly over short distances, and by performing the calculations. After using the audit grid to analyse the lesson, he decided that its key purpose was for pupils to understand and use the equation for measuring speed. To focus on this needed a simpler practical, so he took his pupils out of the classroom and measured their walking speed over a longer distance. This removed procedural difficulties and gave

reliable results, straightforward measurements, better pupil engagement and ultimately more effective learning.

A more significant effect of the audit was a shift in Matt's thinking; a practical activity staged in an appropriate way can be used to teach conceptual understanding *without* an additional theory lesson. Matt's lesson on speed gave him confidence that pupils understood the concept by doing the practical activity. He recognised that with thorough planning and staging of the practical activity (the class needed well prepared resources), pupils would understand the science *through* the practical.

> *"It did take longer to plan and organise the lesson but overall I saved time by teaching the theory through practical. It required confidence to take this step and careful planning and monitoring of the pupils' learning."*

Matt now feels confident in the audit tools, to the extent of using them with newly qualified teachers in his department. He is much clearer about defining the key purpose of practical activities and feels this has significantly improved his teaching.

**Planning for Effectiveness**

This specialist science college with a large sixth form has a strong practical work ethos and offers a wide range of experiences to its pupils including science visits. The school has new science laboratories and is situated within the environs of a large city. Lisa is Key Stage 4 coordinator in the science department.

The science department of this school prides itself on its practical work. The teachers carry out a lot of practical work and believe that it contributes to the popularity and success of the subject, including helping to deliver a high level of progression to A level sciences. This is thought to be because, "the pupils enjoy it; it's a fun way of learning and helps them to see the concepts". Before Lisa's involvement in the Getting Practical project, she felt that the department did not think about why they do practical work, they just assumed that it 'increases pupil's knowledge'.

Lisa found that during the professional development sessions she was prompted to think more about the purpose of her practical activities. She started by ticking a large number of intended learning outcomes for a set of practicals, but found that the process allowed her to clarify and make more realistic the outcomes she wanted to achieve. This process made her think about why she was doing any particular practical, and meant that she was more confident to share the intended outcomes with her pupils.

*"Thinking about why I am using this practical makes me more confident to share achievable learning outcomes with the pupils."*

Lisa feels that process of thinking through *why* particular practical activities are used is one that would be beneficial for her whole department. Their schemes of work have been written to contain many practical activities, but have not been checked to ensure they cover a range of intended learning outcomes. Another result of examining intended learning outcomes was to make a tacit idea explicit; the same practical could be used with different year groups ('maybe with Year 7 for skills and then again in Year 10 to develop knowledge and understanding') simply by changing the emphasis of its intended learning outcomes.

*"I believe we generally are strong in practical work but not always sure why! I feel much more confident that I can lead departmental planning so that we have a more balanced spread of learning outcomes and progression in our practical work."*

In the summer term, the science department will carry out a review of new Key Stage 3 schemes of work as part of their planning for the next academic year. This will

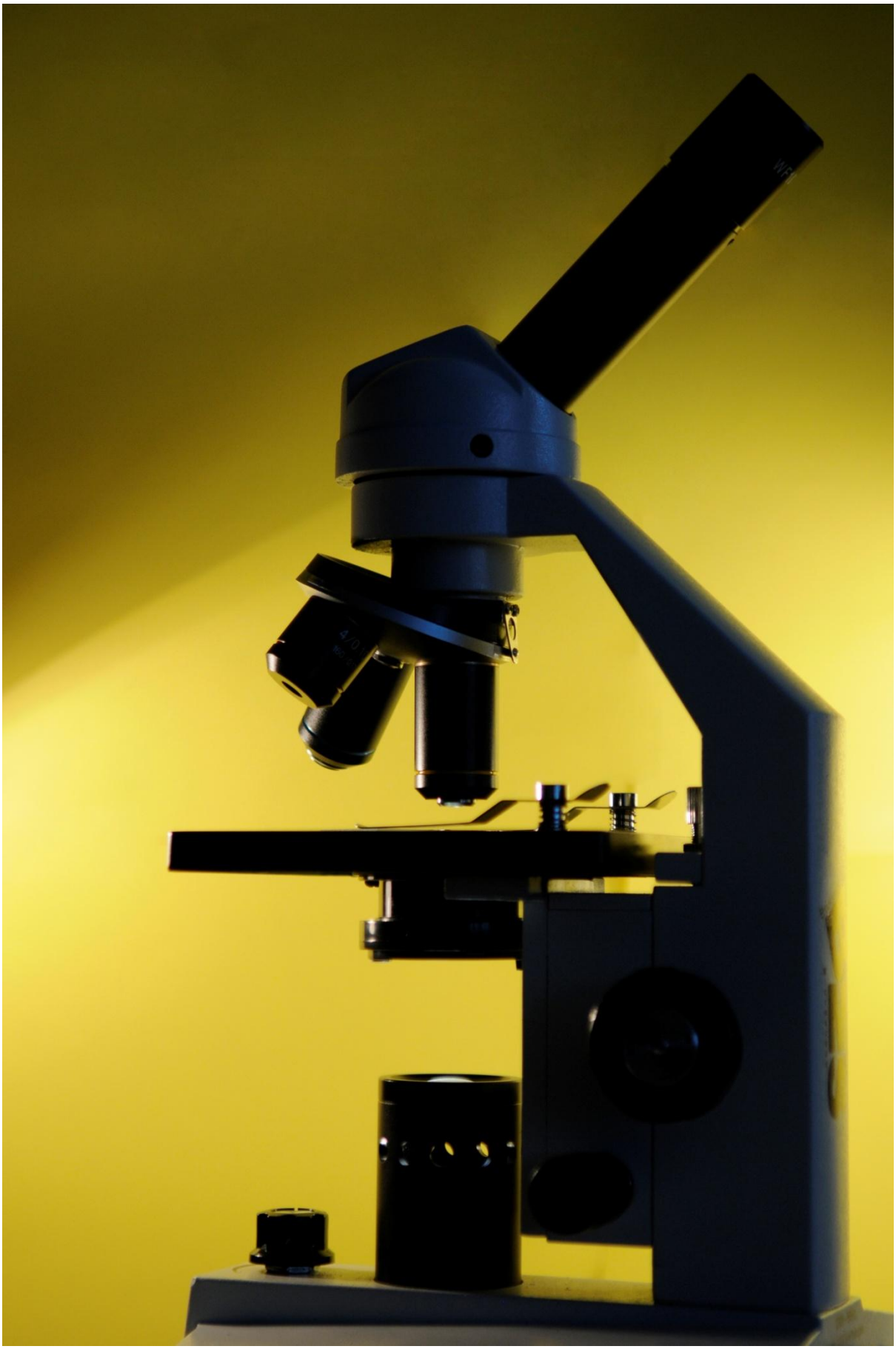
include an audit of the practicals included in the schemes, to clarify their intended learning outcomes, to check for a spread of intended learning outcomes, and to allow for adaptation of the activities if some outcomes are not being tackled in enough depth.

Currently the department is hosting two initial teacher training (ITT) students. They have been introduced to the audit tools and are using them enthusiastically as a check on the practicals they use in their lessons.

For example, following a pair-taught lesson on sweating, the ITT students completed the reflective audit sheet for the practical activity within the lesson. On comparison of their intended learning outcomes with the pupils' actual learning outcomes, it became clear that, while all pupils in the class had gathered results to complete a results table, some pupils had not been able to effectively process or interpret the data from the practical. This prompted a rethinking of the next lessons, to ensure that all pupils had met the intended outcomes.

The audit tool and effectiveness framework helped inexperienced teachers to assess gaps in learning and modify future plans to address these issues.

These early-career teachers were keen to make continued use of this tool, keeping copies of the audits as evidence of reflection, and as a tool to look back on when planning the same activity later. Eventually, they hoped, the process of reflection would become embedded and 'be in our heads', rather than on paper.



## Prioritising the purpose

The science department of this school sees practical work as a vital part of science, with a particular role in developing individual and group work skills. Engagement and enjoyment feature highly within the department ethos of practical work.

Jenny is an experienced science teacher working in a rural community school with a mixed catchment of 850 pupils. Attainment is slightly below national averages. The science department has a positive view of practical work in science.

Jenny holds the view that practical work should be built into learning objectives, to develop scientific knowledge and understanding. She also feels it is important to ensure that, as they progress through their science education, pupils develop and build upon their practical skills.

Her use of the audit tool was with a high ability Year 9 class on forces. The practical investigation involved exploring the force needed to lift a fixed load using different pulley systems. Jenny's focus for this activity was to reinforce 'How Science Works' skills, in particular planning, controlling variables, devising results tables and presenting data.

After completing the audit Jenny was struck by the number of outcomes she expected to achieve in a single lesson. She reflected that this range of objectives meant that no one skill area would be covered in sufficient depth to allow pupils to make real progression.

Jenny noted that although the pupils did what they were asked to in the lesson, she was not confident that they had learnt something that they could then take away from the lesson and apply to other practical work. She identified that the nature of the data provided a challenge to pupils' graphing skills and observed pupils' difficulty in preparing a conclusion based on results from the experiment and in evaluating the procedure.

Reflecting on the key skills of the practical, Jenny modified the way she staged the activity. 'Presenting data effectively' became her main lesson outcome and the evidence of this would be the ability to plot quality graphs of the data obtained. She removed the necessity for pupils to design a results table and provided a version for them to enter data. She also replaced the evaluation section with a plenary activity where pupils are provided with a fictional pupil's graph and assess the work writing corrections and suggestions for improvement.

This is an example of effectiveness level 2 – pupils carry out tasks successfully but do not always learn what the teacher intended.

She feels that using the audit has helped to improve her teaching and has assessed her practice beyond practical work. Examples of this include looking at techniques such as breaking down activities into smaller skill sections, providing pupils with success criteria and allowing them to peer assess each other's work.

Jenny feels the audit process will provide an overview of the coverage and progression of skills across her department's schemes of work. It will help them to identify which practical activities are appropriate for developing certain skill areas, and as a result they plan to systematically build a series of practical activities into their schemes that ensure full coverage of the skills they are aiming to develop with their pupils.

*'I feel this would be much more productive way of developing understanding of scientific enquiry rather than inserting activities into a scheme and just assuming that all skills will be covered.'*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**Doing less better - changing the departmental approach**

The school is an 11-16 community school. With 1000 pupils on roll, it became a specialist mathematics and computing school in 2006. It is a challenging school and in the 2009 Ofsted inspection it was given notice to improve. Sarah is Key Stage 3 science coordinator.

Prior to a recent Ofsted visit this department largely adopted a recipe driven approach to practical work. The pupils followed prescriptive tasks without truly understanding the purpose of the activity. There was a feeling from some teachers that there wasn't enough time to do practical work and instead they should concentrate on teaching content. Following Ofsted's visit, the department refocused its aims, with an emphasis on independent learning and investigation. The 'Getting Practical' audit tools provided a timely intervention to aid this change.

An experienced teacher, Sarah found the audit tools helpful in her own teaching. She now regularly sets a learning objective focussed on practical work and has observed positive responses, particularly in developing practical skills, since pupils working at all levels can achieve success in this area. Sarah also used the audits to ensure coverage of a spread of learning outcomes over a half term, using activities such as *modelling the small intestine* (concentrating on developing scientific knowledge and understanding), *making a specimen of an onion cell* (focussing on developing practical skills) and *how does caffeine affect reaction times* (to develop enquiry skills).

By reflecting on the key purpose of the activity Sarah is able to plan for progression more effectively.

Sarah also found that the audit sheets revealed a number of key issues. For example, she found that one practical lacked open-endedness; it required a more investigative approach to ensure effectiveness. The audit revealed that most of her practical learning outcomes started with 'state' rather than 'plan', evaluate' or 'process'. Tasks were therefore limited in demand on her pupils by her own expectations. She is now extending her range of strategies for gathering evidence of effectiveness, including questioning pupils carefully, listening to their dialogue as they work and examining follow-up written work.

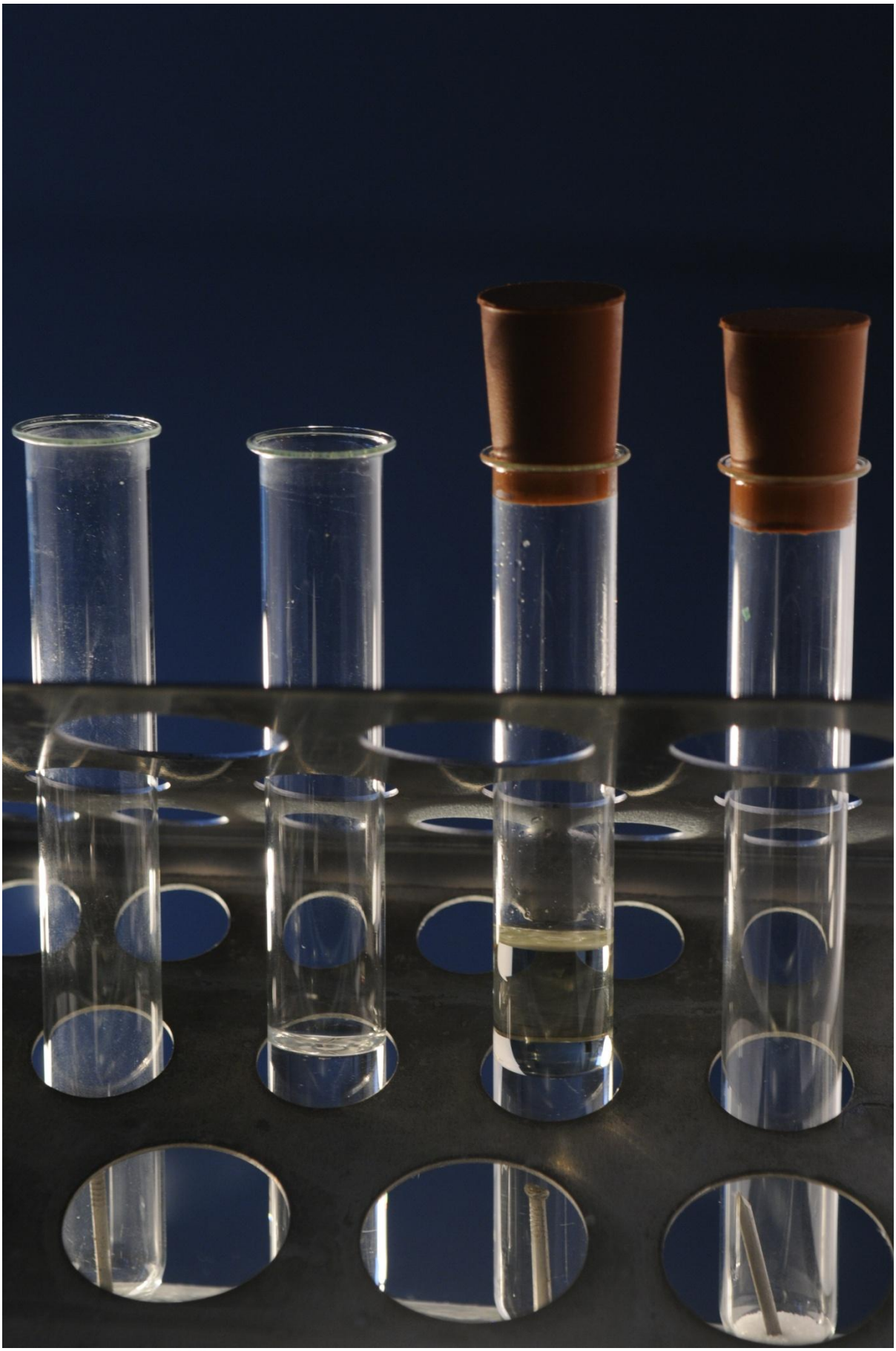
Working with colleagues to explore the effectiveness of the department's practical work uncovered a number of issues, including ensuring that the three groups of intended learning outcomes were understood and that there can, and should, different reasons to do practical work. She is encouraging staff to see practical work as an integral part of learning, not just an 'add on'. Less experienced members of the team now talking about practical work more with her (as curriculum

leader for Key Stage 3) and each other, indicating that, as a result of the Getting Practical project, the profile and status of practical work have been successfully raised in the department.

The majority of teachers in the department carried out a modelling practical and shared the outcomes at a staff meeting, leading to a review of departmental schemes of work using the audit tools. It became clear that some of their existing practicals had too many expected learning outcomes and as a consequence were often ineffective.

It also became apparent that their practical activities did not allow development of a full range of learning opportunities. The department is now aiming to embed a new set of practical investigations that cover all the practical and enquiry skills needed at Key Stage 3, and teachers are now doing much more investigative work.

*'The main difference this project has made is in learning to evaluate what we do already do and improve it rather than reinvent the wheel. Many of us had got stuck in a rut and had seen practical work as something extra to do rather than integral and beneficial to learning.'*



**Summary**

The mapping activities described in this booklet are intentionally simple and straightforward. They do not need new equipment, activities or major changes to teaching methods and approaches. What they do require is for teachers to examine their pedagogy, their understanding of how they teach and how their pupils learn.

This may been seen as low priority or even an unnecessary burden ("*I know how to do practical, thinking about it won't make any difference"*) but our observations of the activities in action has revealed enlightening moments for even the most experienced as the logic of the approach becomes clear.

> I think it's just clicked; I've been doing this for years and now understand why!

The use of the mapping activities is not recommended as a mechanistic approach to all lesson planning, but going through this process periodically is sufficient to create a positive change in approach and attitude.

There is concern throughout the science community that the status of practical work is in decline; this is the origin of the SCORE report. Many writers on this subject refer sensibly not to the quantity but to the quality of practical work (Wellington, 1998). It is this issue that the mapping activities in this booklet seek to address.

Practical work has always been an essential part of science teaching and will rightly remain so, but the teacher today has many other strategies in their armoury: ICT, argument and discussion, role play and simulation, high quality text, video, broadcast media and newspapers. All activities should stimulate, engage and motivate young people in their learning of science and practical work is no exception. It has to be planned with clear objectives and intended learning outcomes, and as an integral part of a well thought-out teaching sequence which will enable progression for all pupils.

The arguments about the importance of a good science education from both the individual's and society's perspectives are well rehearsed and documented. Ask anyone to relate a memory of their science education and they will undoubtedly recall an experiment (often going wrong!); ask a casual observer what they would expect to see in a science lesson and they will say experiments. As teachers we know that there is more to science education than this and we know that effective practical work is a central component of successful science teaching. The challenges set out here are to be clear in the purpose of practical work, to,choose practical activities which meet learning

objectives, to stage activities to meet objectives, and to monitor and reflect on the outcomes of the practical experience.

We hope that in the activities outlined in this booklet will ‘turn on the light’ in a practical sense and help you to make the practical experiences of pupils purposeful, engaging and effective.

**Recommended Reading**

Millar, R. (2010) *Analysing Practical Science Activities to Assess and Improve Their Effectiveness*, Hatfield: Association for Science Education

The National Strategies (2008) *Interactive Practicals Science Study Guide*, Department for Children, Schools and Families. Available to download from http://nationalstrategies.standards.dcsf.gov.uk/node/284937 [version current at April 2010]

SCORE (Science Community Representing Education) (2008) *Practical Work in Science: A report and proposal for a strategic framework*, Gatsby Technical Education Projects. Available to download from http://www.score-education.org/2projects/practical_work.htm [version current at April 2010]

**Other useful references**

Abrahams, I. and Millar, R. (2008) Does Practical Work Really Work? A study of the effectiveness of practical work as a teaching and learning method in school science, *International Journal of Science Education* 30(14): 1945-1969

Millar, R. (2009) *Analysing practical activities to assess and improve effectiveness: The Practical Activity Analysis Inventory (PAAI)* York: Centre for Innovation and Research in Science Education, University of York. Available to download from http://www.york.ac.uk/depts/educ/research/ResearchPaperSeries/index.htm [version current at April 2010]

Tiberghien, A., Veillard, L., Le Marechal, J-F., Buty, C., Millar, R. (2001). An Analysis of Labwork Tasks Used in Science Teaching at Upper Secondary School and University Levels in Several European Countries, *Science Education*, 85 (5): 483-508

Wellington, J.J. (1998) *Practical Work in School Science: Which Way Now?*, Routledge: London