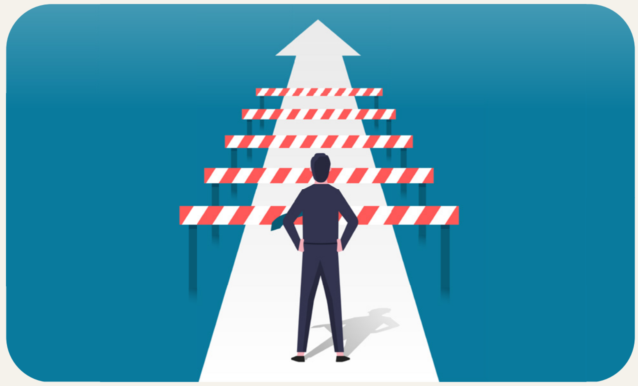
Possible barriers to the effective use of practical work in school science



Ian Abrahams and **Nikolaos Fotou**

Abstract

Practical work can play a very important role in the teaching and learning process in school science in contributing towards the development of students' understanding of scientific processes and concepts, as well as in generating a positive attitude towards science in general. The purpose of this article is to identify barriers that hinder the effective use of practical work in secondary school science and to consider approaches that might help to overcome those barriers. The article distinguishes between barriers relating to resources and assessment and those that relate to teachers and technicians.

Many within the science education community (e.g. Chala, 2019) have argued that practical work, as it is generally used, is an essential tool for the teaching and learning of science. Its use, it is believed, not only develops students' understanding of scientific concepts, practical skills and the process of scientific investigation (e.g. Woodley, 2009), but also nurtures essential life skills such as critical thinking, problem-solving and teamwork. Interestingly, and despite such widely shared beliefs, there is still surprisingly little research evidence to show that practical work, as frequently used, is effective in developing scientific conceptual understanding (Abrahams and Millar, 2008), or that it provides an effective means of developing essential life skills such as critical thinking or problem-solving. At a more fundamental level, although the term 'practical skills' is widely used, what these skills actually are and how they might most effectively be validly assessed remains unclear (Abrahams, Reiss and Sharpe, 2013). Hodson (1991) claimed that '*as practised in many countries, it [practical work] is ill-conceived, confused and unproductive. For many children, what goes on in the laboratory contributes little to their learning of science*' (p. 176). This article focuses on providing an overview of possible barriers to both its *effective use* and its *affective value* (Box 1) and will also, briefly, consider the barriers to the use of more practical work.

Box 1 Affective versus effective

When referring to the *affective value* of practical work, we use the term to refer to the emotions, or feelings, engendered in students towards science in general or one or more of the school sciences in particular, through its use (Abrahams, 2009). In contrast, the *effectiveness* of practical work is used to refer to the match between what the teacher intended their students to do and learn, both within the domain of objects and observables and/or within the domain of ideas, and what their students actually did and learnt (Millar and Abrahams, 2009).

Overcoming barriers to doing 'more of the same' practical work

Resources

Resources, in the context of practical work, include not only the physical equipment and materials needed to undertake experiments, but also the funding and infrastructure that support these activities, including the cost of non-teaching technical support. Lack of resources is a complex issue and one that can manifest itself in numerous ways, ranging from inadequate laboratory space and insufficient teaching materials, to a lack of laboratory technical support. Again, part of the problem here is that without clear, unambiguous research evidence that shows that the use of practical work, with all the additional resource requirements that it entails, is more effective or affective than non-practical approaches for teaching the same content, then it becomes difficult for those advocating for the use of practical work to make the case for additional resource funding. Interestingly, while a commonly identified barrier to the use of practical work is the lack of sufficient resources (e.g. Dillon, 2010), a study of schools in South Africa (Hattingh, 2007) found that, while this can create barriers, teachers who were motivated to use practical work, and believed in its value, invariably found ways to overcome this barrier and did so even in the most poorly resourced schools in the study. Indeed, a study of secondary schools in Morocco (Menchafou, Aaboud and Chekour, 2024) found that the use of less-expensive, virtual laboratories as a means to overcome resource shortages was not only comparable to traditional experimental activities, both in terms of usability and effectiveness, but led to substantially better student performance.

Technical support

Another barrier to doing 'more of the same' practical work can be a lack of technical support and the fact that in many UK secondary schools the role of the science technician has been found to be poorly understood or underrated by the senior management (CLEAPSS, 2009). The consequences, as Soares and Lock (2007) have argued, can manifest themselves both in a lack of technical support for science teachers in terms of preparation or their delivery of practical work, and in the creation of barriers to the training and career development of technicians, which can result in much-needed technicians leaving the role. To address these issues, and in light of teacher shortages in *some* science subject areas, one solution might be to further encourage, through directed government funding, opportunities for laboratory technicians to become teaching assistants in shortage subject areas (where some of them have a wealth of expertise in terms of practical work), thereby enabling them to actively contribute to the delivery, as well as the preparation, of practical science lessons.

'In many UK secondary schools the role of the science technician has been found to be poorly understood or underrated by the senior management.'

Practical skills

In terms of the practical skills themselves, Abrahams, Reiss and Sharpe (2016) reported that, while these are clearly believed to be of importance, there is a lack of both clarity and consensus as to what these skills actually are, and how they might most effectively be validly assessed. They found that countries differed greatly in the extent to which they employed either Direct Assessment of Practical Skills (DAPS) or Indirect Assessment of Practical Skills (IAPS) and that, while each approach has advantages and disadvantages, too great a reliance on IAPS reduces the likelihood that practical work will be taught and learnt as well as it might be. Indeed, part of the reason for that relates to the pressure of standardised testing and accountability, and the emphasis on high-stakes exams that can hinder the integration of effective practical work into the teaching of science. In systems where final exams heavily assess theoretical knowledge, teachers may, understandably, feel the need to focus primarily on preparing students for these exams. Consequently, practical work that may not be directly assessed in exams often takes a back seat in favour of more content-driven teaching. However, this is an example of where further research is needed; if, as is frequently claimed, practical work is as effective, or more effective, in developing conceptual understanding than non-practical work, then teachers would want to make more use of it. The fact that teachers frequently choose not to use practical work might therefore indicate that when it comes to the development of conceptual understanding, non-practical approaches to teaching are viewed as the most effective pedagogy to use.

Having briefly considered the barriers to the delivery of 'more of the same', barriers that are essentially financial in nature and over which schools and science departments have little control, our focus will now shift to barriers over which schools, and science teachers in particular, do have a greater element of control.

Overcoming barriers to the use of more effective and affective practical work

Few in the science education community will doubt that practical work will continue to play a central role in the teaching of science for the foreseeable future. The challenge, identified by Millar and Abrahams (2009), is therefore not about barriers to the use of practical work per se, but about overcoming the barriers to making the practical work that is used more effective as a teaching and learning strategy than it often is at present, as well as those barriers that might reduce its enduring affective value. Barriers to the effective and affective use of practical work can be seen to fall into three broad categories that relate to a lack of clarity with respect to:

- the identification of learning objectives, and how these might be effectively achieved through practical work;
- an informed analysis of the learning demands of practical tasks;
- the design and presentation of a practical task in a manner that assists students in *thinking* about their actions (the '*doing*') and their data in the way that the teacher intends.

From this perspective, the barriers to be overcome do not necessarily reflect a lack of material resources, but rather a lack of understanding about when and how to use practical work effectively and in a manner that enhances an enduring affective value.

'When it comes to the development of conceptual understanding, non-practical approaches to teaching are viewed as the most effective pedagogy to use.'

The advantage of focusing on overcoming the barriers to the use of more effective and affective practical work, rather than simply on the use of practical work per se, is that the focus is therefore shifted towards what teachers themselves, with the same resources as they currently have, can do to overcome those barriers. In so doing, it raises questions about the purpose of practical work and how to maximise its effectiveness and affective value – questions that those who fund and direct educational research can also seek to address.

A key finding, from a study of secondary school practical science lessons by Abrahams and Millar (2008), was that the majority of practical work time did not entail thinking about ideas and the associated development of conceptual understanding, but rather focused on the recipe-style 'doing' with objects and materials. An important consequence following from that research is that practical work, as frequently used, is not an effective use of teaching time if the aim is to develop students' conceptual understanding. Even if it were possible to find the time to simply do more of the same type of practical work, this is unlikely to have any measurable benefits in enhancing student conceptual understanding. The barrier to be raised is therefore not simply about doing practical work, but doing practical work that is effective in developing conceptual understanding. The removal of that barrier can be facilitated if teachers better recognise the scale of the cognitive challenge students face in linking their actions and observations to a framework of ideas, and, as a consequence, divide practical lesson time more equitably between 'doing' and 'learning'. However, despite the importance of making such an equitable division, there is a need to recognise, especially when teaching outside of a subject specialism (e.g. a biology teacher teaching a key stage 4 (age 14–16) chemistry practical lesson) that many science teachers rely on ‘recipes’, which might focus almost exclusively on ‘doing’ rather than ‘learning’. If, however, the scale of the cognitive challenge for students in linking their actions and observations to a framework of ideas is better appreciated, teachers might then be guided towards using ‘new recipes’ that do divide practical lesson time more equitably between ‘doing’ and ‘learning’. These do not, of course, have to be rigidly separated, but teachers need (Abrahams and Millar, 2008) to regularly devote a greater proportion of the lesson time to helping students use the ideas associated with the phenomena they have produced, rather than seeing the successful production of the phenomenon as an end in itself. Indeed, as scientific ideas do not emerge unaided, simply as a result of producing and observing phenomena, it has been suggested (Fotou and Abrahams, 2015) that teachers might use more of the practical lesson ‘doing’ time to help students, through the use of analogies and metaphors, to ‘see’ the phenomena in the same ‘scientific way’ that they, the teacher, ‘sees’ them.

‘More research is needed specifically to compare the effectiveness of practical work with non-practical alternatives for the teaching of specific concepts.’

Overcoming these barriers can be partly initiated by a bottom-up introduction of new research-informed teaching ideas – those that trainee/early career science teachers can bring with them into their schools as a result of their recent engagement with current research-based findings in their higher education training establishments. However, there can sometimes be a top-down resistance to change in the use, or manner of use, of practical work that can reflect the views and opinions of more experienced science teachers who have always done it ‘their way’. Indeed, the need to mitigate against such top-down resistance was one of the underpinning rationales, established by the White Rose University Consortium, for science teachers’ continuing professional development (CPD) that was contained in their proposal to the UK Department for Education and Skills for funding to develop a national network of Science Learning Centres. The argument made was that science teachers should have the same rights to, and provisions of, CPD as was available to other professions (e.g. lawyers). The CPD should be designed to support science teachers in enhancing and updating their professional skills by learning more about contemporary scientific ideas, experimenting with effective teaching approaches and gaining experience of modern scientific techniques. Undertaking it should be seen as a condition of being able to continue to practise as science teachers (White Rose University Consortium Team, 2005).

The current lack of understanding about the need to better integrate ‘doing’ and ‘learning’ can undermine the effectiveness of using practical work for developing conceptual understanding (Millar and Abrahams, 2009). A similar lack of understanding about the affective value of practical work can mean that its use will not meet the affective objectives that the teacher believes its use will generate. In this respect, CPD could play an important part in introducing science teachers to the research findings about the *actual* affective value of practical work: while the common perception among teachers is that its use *motivates* students (Wellington, 2005), the research shows that, in a strict psychological sense, its impact is better understood as non-enduring situational interest (Abrahams and Sharpe, 2010). The fact that situational interest is, in contrast to motivation or personal interest, unlikely to endure beyond the end of a particular practical lesson, helps to explain why students need to be continually re-stimulated by the frequent use of practical work. Once teachers are better aware of this finding, the reason why many of their students who claim to like practical work also claim to have little, if any, personal interest in science, or any intention of pursuing it post-compulsion, becomes clearer. It also provides science teachers with an explanation as to why, despite the frequent and widespread use of practical work in secondary school science lessons (Bennett, 2003), and their belief in its motivational value, the number of students choosing to pursue A-levels in chemistry or physics, arguably the two science subjects that offer the most practical work during key stages 3 and 4 (ages 11–16), is generally lower than for biology that offers the least (UK Government Official Statistics, 2024).

More research is needed specifically to compare the effectiveness of practical work with non-practical alternatives for the teaching of specific concepts to enable science teachers, on the basis of those findings, to make informed choices as to when to use practical work. Interestingly, part of the difficulty with the teaching of science can be that, unlike most other school subjects, science is a core subject in key stage 4 and, as such, requires the sustained use of practical work over a longer period. That need for science teachers to use practical work for those two *additional* years of study occurs despite the fact that many of the students studying science at key stage 4 will not pursue a science A-level, and the current lack of research evidence to show that the use of practical work at key stage 4 has a measurable, lasting, impact on those students in terms of life skills such as the development of critical thinking, problem-solving and teamwork. Indeed, it has been reported (Abrahams, 2009) that students find the novelty of being in a laboratory environment and of undertaking practical work wears off relatively quickly, and they become increasingly disillusioned by the reality of school science, which they perceive as being very different from the image of science that science teachers initially create to make their subject appear attractive on open days. Such an argument does not negate the possible, short-term affective value of practical work as a means of providing a coping strategy for science teachers faced with teaching science to students, especially in key stage 4, many of whom have little, if any, personal interest in science. However, given the shortage of science teachers – especially in chemistry and physics – it does suggest that we need more research-based evidence of the benefits of requiring science, unlike subjects such as geography, history or modern foreign languages, to be a core subject, and how we can maximise the effectiveness of using practical work to develop life skills such as problem-solving, given that many of those students will not pursue science post-compulsion.

Conclusion

In summary, there is a need to recognise that the two most important barriers to the use of practical work that need to be overcome are those that prevent its more effective use in developing students' conceptual understanding and that reduce its affective value, rather than simply barriers to using more practical work per se. Furthermore, more research is needed from the science education research community, and those that fund and direct the course of research in science education, on the skills that practical work is claimed to generate and its effectiveness in doing so; for example, the effectiveness of practical work compared with sport as a means of developing teamwork skills. With limited resources and funding, research evidence is needed to support the claim that the additional two years of compulsory science for all at key stage 4 has a measurable, lasting and beneficial impact on students, and that the benefits of those additional two years of study more than offset the associated costs of delivery and the shortage of science teachers that such a requirement creates.

We conclude by emphasising that this article is not intended as a definitive cure-all but rather as an overview and an opportunity to pause for thought. Some further reading is suggested for those with the time and interest.

FURTHER READING

Gericke, N., Högström, P. and Wallin, J. (2023) A systematic review of research on laboratory work in secondary school. *Studies in Science Education*, **59**(2), 245–285.

Millar, R. (1998) Rhetoric and reality: what practical work in science education is really for. In *Practical Work in School Science: Which Way Now?* ed. Wellington, J. pp. 16–31. London: Routledge.

Osborne, J. F. (1996) Untying the Gordian Knot: diminishing the role of practical work. *Physics Education*, **31**(5), 271–278.

Woolnough, B. and Allsop, T. (1986) *Practical Work in Science*. Cambridge: Cambridge University Press.

REFERENCES

Abrahams, I. (2009) Does practical work really motivate? A study of the affective value of practical work in secondary school science. *International Journal of Science Education*, **31**(17), 2335–2353.

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.

Abrahams, I., Reiss, M. J. and Sharpe, R. (2016) To DAPS or to IAPS: that is the question. In *Science Education Research and Practical Work*, ed. Eilks, I., Markic, S. and Ralle, B. pp. 119–130. Germany: Shaker Verlag.

Abrahams, I. and Sharpe, R. (2010) Untangling what teachers mean by the motivational value of practical work. *School Science Review*, **92**(339), 111–115.

Bennett, J. (2003) *Teaching and Learning Science: A Guide to Recent Research and its Applications*. London: Continuum.

Chala, A. A. (2019) Practice and challenges facing practical work implementation in natural science subjects at secondary schools. *Journal of Education and Practice*, **10**(31), 1–17.

CLEAPSS (2009) *G228 – Technicians and their Jobs*. Uxbridge.

Dillon, J. (2010) Effective practical science. *School Science Review*, **91**(337), 36–39.

Fotou, N. and Abrahams, I. (2015) Doing with ideas: the role of talk in effective practical work in science. *School Science Review*, **96**(359), 55–60.

Haste, H. (2004) *Science in my Future: A study of Values and Beliefs in Relation to Science and Technology Amongst 11–21 Year Olds*. London, Nestlé Social Research Programme.

Hattingh, A. (2007) Some factors influencing the quality of practical work in science classrooms. *African Journal of Research in SMT Education*, **11**(1), 75–90.

Hodson, D. (1991) Practical work in science: time for a reappraisal. *Studies in Science Education*, **19**(1), 175–184.

Menchafou, Y., Aaboud, M. and Chekour, M. (2024) Effectiveness of virtual labs for physics learning in Moroccan secondary schools. *International Journal of Interactive Mobile Technologies*, **18**(15), 129–143.

Millar, R. and Abrahams, I. (2009) Practical work: making it more effective. *School Science Review*, **91**(334), 59–64.

Soares, A. and Lock, R. (2007) Pre-service science teachers' perceptions of written lesson appraisals: the impact of styles of mentoring. *European Journal of Teacher Education*, **30**(1), 75–90.

UK Government Official Statistics (2024) *Provisional entries for GCSE, AS and A level: Summer 2024 exam series.* https://www.gov.uk/government/statistics/provisional-entries-for-gcse-as-and-a-level-summer-2024-exam-series/provisional-entries-for-gcse-as-and-a-level-summer-2024-exam-series#as-and-a-level-entries

Wellington, J. (2005) Practical work in the affective domain. In *Beyond Cartesian Dualism: Encountering Affect in the Teaching and Learning of Science*, ed. Alsop, S. 99–110. Dordrecht: Springer.

White Rose University Consortium Team (2005) The continuing professional development of science teachers: a discussion paper. *School Science Review*, **87**(318), 105–111.

Woodley, E. (2009) Practical work in school science – why is it important? *School Science Review*, **91**(335), 49–51.

Ian Abrahams
Professor of Science Education and Director of the Centre for Educational Research at the University of Roehampton
ian.abrahams@roehampton.ac.uk
Nikolaos Fotou
Senior Lecturer and MA Arts in Education Program Lead at the University of Lincoln
nfotou@lincoln.ac.uk