

The assessment of practical skills

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ABSTRACT

Major changes are currently afoot as to how practical work will be assessed in high status examinations (GCSEs for 16-year-olds and A-levels for 18-year-olds) in England. We explore here how practical skills might best be assessed in school science and introduce two terms: direct assessment of practical skills (DAPS) and indirect assessment of practical skills (IAPS). We conclude that both the direct and indirect assessment of practical skills have their place in effective assessment of school science and that too great a reliance on the indirect assessment of practical skills will lead to assessment that is less valid.

Recent research in the area of practical work (Abrahams and Reiss, 2012) and in the assessment of science education more broadly (Bernholt, Neumann and Nentwig, 2012) describes the significant influence of the curriculum and, in particular, its associated assessment on the practical work that teachers opt to do. In England, at GCSE and A-level, it has long been recognised (Donnelly, 2000) that, to a very considerable extent, it is assessment that drives what is taught, to the extent that teachers' preferences for using different types of practical work are routinely influenced by their considerations of curriculum targets and methods of assessment. In order for assessment to be effective, it is necessary to know what it is that is being assessed, be that conceptual understanding, procedural understanding, process skills or practical skills. In order to assess these areas, it is necessary to understand the meanings of these terms. (Glossary is provided in Box 1.) For the first two of these terms, Gott and Duggan (2002: 186) suggest: By conceptual understanding we mean a knowledge base of substantive concepts such as the laws of motion, solubility or respiration which are underpinned by scientific facts. By procedural understanding we mean 'the thinking behind the doing' of science and include concepts such as deciding how many measurements to take, over what range and with what sample, how to interpret the pattern in the resulting data and how to evaluate the whole task.

While process skills are those that are 'generalisable', transferable from one context to another and readily applicable in any context' (Hodson, 1994: 159), the term 'practical skills', while often referred to in the literature on practical work (cf. Bennett and Kennedy, 2001), is, perhaps surprisingly, rarely explicitly defined. Indeed, part of the problem we would suggest is that, while practical skills clearly include an individual's competency in the manipulation of a particular piece of apparatus/equipment, there are so many such skills that it becomes unfeasible to assess a student's competency in all of them within the limited time available in school science.

In order to explain how these terms relate in the context of science practical work, consider case in which a teacher, when teaching electricity, wants to use a practical task to demonstrate the conservation of current in a parallel circuit. The procedural understanding in this case would entail knowing how, in theory, to set up working parallel circuit and operate and read with sufficient accuracy an ammeter to obtain the readings in the manner intended by the teacher. The conceptual understanding would be to know that the data obtained from the ammeter readings can be understood in terms of the scientific idea that the flow of electric charge is conserved in a parallel circuit. The process skills would refer to the ability to follow the instructions provided by the teacher

and understand the generic issues relating to fair tests and measurement errors. Finally, the practical skills would, in this example, relate to the student's competency in actually setting up the working electrical circuit using the materials and equipment available. However, while useful for clarifying how it relates to 'process skills', this is a narrow understanding of the term 'practical skills'. Many would want to include 'process skills' within the term 'practical skills', with the expectation that the acquisition of such skills would enhance both procedural and conceptual understanding (as defined above).

The role of assessment of practical work in science lessons (practical work being a substantial component of what was formerly known in the Science National Curriculum in England as Sc1) has been commented on (Donnelly, 2000: 28) as being primarily used for assessment towards specific examinations rather than for the skills it may provide: ... it appears that Sc1 is most commonly used for purposes of assessment, and more rarely taught, either for the sake of the skills it is intended to promote or as a vehicle for the teaching of scientific content. (There is perhaps an ambiguity here, with teachers indicating that they very often use Sc1 for assessment purposes, rather than that they very often undertake assessment of Sc1.) Indeed, as Nott and Wellington (1999: 17) note: The skills and processes of investigations are not taught, but experienced, and the conductor investigations is about summative marks rather than formative assessment to become a competent scientist. In that both pupils and teachers see them as more about getting marks than learning some science, the assessment tail is definitely wagging the science dog. In a study by Bennett and Kennedy (2001: 108) they reported on 'the inadequacies in the current model of assessment of practical skills and abilities, with written examinations [sic] questions on practical work examining only a very limited range of abilities'. Indeed, changes in the way practical work is used in schools has meant, as Toplis and Allen (2012: 5) discuss, that there has been: ... a shift in England and Wales since the 1960's away from practical work for teaching apparatus handling skills and towards augmentation of knowledge and understanding of substantive concepts, and 21st century UK school science has little to do with the formal assessment of these skills. We believe that, as practice in schools is largely led by assessment pressure, if there is a desire for teachers to re-focus some of the time spent in doing practical work on developing actual practical skills that will be useful for further study and/or employment then it is important that students' competency in such practical skills is formally included in the summative assessment process. Whereas Welford, Harlen and Schofield (1985: 51) suggest, in a report on the testing of practical skills in science for ages 11, 13 and 15, that 'the assessment of practical skills maybe possible from pupils' reports or write-ups – provided that they have actually carried out the practical or investigation prior to putting pen to paper [bold in original]', we would suggest that practical skills are, in many cases, best assessed directly. For example, while a conceptual understanding of the topology of knots and manifolds might well be assessed by a written task, the most effective means of assessing whether a student is competent in tying their shoe laces is to actually watch them as they attempt to tie them. In this respect we feel that a useful distinction can be made between what we refer to as the direct assessment of practical skills (DAPS) and the indirect assessment of practical skills (IAPS) (Abrahams, Reiss and Sharpe, 2013). The former, DAPS, refers to any form of assessment that requires students, through the physical manipulation of real objects, to directly demonstrate a specific or generic skill in a manner that can be used to determine their level of competency in that skill. An example of this would be if a student was assessed on their skill in actually using an ammeter (in contrast to describing either orally or in writing how they would envisage using an ammeter) and this was determined by

requiring them to manipulate a real ammeter, use it within a circuit to take readings, and for these readings to need to be within an acceptable range for the student to be credited. In contrast, IAPS relates to any form of assessment in which a student's level of competency, again in terms of a specific or generic skill, is indirectly inferred from information they provide, such as reports of the practical work that they undertook or are planning to undertake (e.g. if one is assessing the skill of planning). For example, in indirectly assessing a particular student's competency in the use of an ammeter when the student is working in a group of students who have access to a single ammeter, the marker might be required to make a judgement on the basis of what that student reported they had done (or would do) even if, within the group in which they had undertaken the practical task, the ammeter had (although this might not be reported) only been used by another student.

A common example of the need to use both DAPS and IAPS to best assess both a learner's practical skills (understood broadly to include process skills) and conceptual understanding, respectively, and one that we consider provides a useful analogy, is the UK driving test. In this example, not only does the candidate have to demonstrate a sufficient level of competency directly when actually driving on the road (DAPS) but they must also pass an online test to assess their understanding of how to drive a car safely and competently (IAPS). Table 1 shows a comparison between DAPS and IAPS. There are, we recognise, many cases when the use of IAPS can provide reliable and valid means of assessment. However, the current dominance of IAPS within summative assessment of practical work in science in England means that the focus has been directed on to what students know about practical work and how it should, at least in theory, be undertaken rather than on their competency in terms of actually being able to do practical work. This does not, we suggest, seem the best way to assess a student's competency in terms of the practical skills required to make up a buffer solution, use an oscilloscope or prepare a microscope slide. Indeed, over-reliance on IAPS for the assessment of practical work has the potential to lead teachers and students to focus on mastering only 'minds-on' rather than 'hands-on' and 'minds-on' science. Table 2 shows a range of practical assessments, not restricted to science, and examples from each, as well as indicating whether these are DAPS or IAPS.

Conclusion

Both DAPS and IAPS have advantages and disadvantages. In deciding when DAPS or IAPS is more appropriate, our recommendation is that if the intention is to determine students' competency in terms of actual practical skills then DAPS is generally more appropriate. Conversely, if the intention is to determine students' understanding of a skill or process then IAPS is generally more appropriate. While DAPS does not necessarily require teachers to undertake the assessment (an external examiner might be used), a recent report from the Nuffield Foundation on the assessment of primary science has called for a greater role for teachers in the assessment process (Harlen et al., 2012). We believe, given the numbers of students involved and the potential higher costs of employing more staff, teachers should be involved in the direct assessment of practical skills. A number of other countries (including ones that perform well on international league tables for school science) manage such teacher internal assessment successfully (Abrahams et al., 2013). Acknowledgements We are grateful to the Gatsby Charitable Foundation for funding and to Rachael Sharpe for valuable discussions.

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BOX 1 Glossary of terminology

Direct assessment of practical skills (DAPS): Where students' skills are assessed either in the presence of the person who is awarding marks (e.g. when observing the manipulation of objects in science) or when a record is made (e.g. an audio-tape recording when assessing oral skills in modern foreign languages) and sent to the person who is awarding marks.

Formative assessment: Assessment for learning, where students are given feedback from the teacher during the teaching they receive in order to progress as opposed to being given a final assessment of their learning.

Indirect assessment of practical skills (IAPS): Where students' skills are inferred in a written examination or through some other secondary form of assessment.

Internal assessment: Assessment carried out in the centre (school/college), marked by the teacher and moderated by the awarding body. This is the coursework within a qualification. Within science qualifications, 'internal assessment' generally refers to practical work assessment.

Process skills: Generic skills such as, in science, observation, measurement, sorting/classifying, planning, predicting, experimenting and communication. Depending on definitions, such process skills may be distinguished from practical skills or included within them.

Practical skills: Skills necessary for undertaking a non-written task, e.g. performing a titration, reading an oscilloscope, playing an arpeggio, ordering a meal in a foreign language. A narrow understanding of practical skills in science distinguishes them from process skills in science, so that practical skills in science are more specific (e.g. 'can focus a light microscope at a range of magnifications') and process skills in science are more generic.

Summative assessment: Assessment of the learning, where the marks are for a terminal test or examination.

Table 1 A comparison of the direct assessment of practical skills (DAPS) and the indirect assessment of practical skills (IAPS); reproduced from Reiss, Abrahams and Sharpe (2012)

DAPS	IAPS
What is the principle of the assessment? A student's competency at the manipulation of real objects is directly determined as they manifest a particular skill	A student's competency at the manipulation of real objects is inferred from their data and/ or reports of the practical work they undertook
How is the assessment undertaken? Observations of students as they undertake a piece of practical work	Marking of student reports written immediately after they undertook a piece of practical work or marking of a written examination paper subsequently taken by students
Advantages	High validity
Encourages teachers to ensure that students gain expertise at the practical skills that will be assessed	More straightforward for those who are undertaking the assessment
Disadvantages	More costly
Requires teachers or others to be trained to undertake the assessment	Has greater moderation requirements
Lower validity	Less likely to raise students' level of practical skills

Table 2 Range of practical assessments currently in use and whether these are DAPS or IAPS; reproduced from Reiss, Abrahams and Sharpe (2012)

Practical assessment in use	DAPS or IAPS?
Report on an investigation – students write their report on an investigation using their own data but their practical skills are not observed or assessed directly	IAPS
Report on an investigation – students write their report on an investigation using data with which they have been provided (typically because of a problem that has prevented the student from obtaining any meaningful data)	IAPS
Written examination – students complete a test paper under examination conditions	IAPS
Practical examination report – students conduct a practical and write up their apparatus, methods, results	DAPS

and evaluations IAPS Viva – students are given an oral examination in which they are asked questions about a project they have undertaken IAPS Practical examination – teacher (or other examiner) observes students undertaking practical work DAPS Practical examination by means of recording – examiner listens to an audio recording, e.g. of a student singing or playing a musical instrument, or watches a video recording, e.g. of a rehearsal of a play DAPS Practical examination by means of observation of an artefact – examiner views a painting made in art or a product made in design and technology