School science practical work in a COVID-19 world:

Are demonstrations, videos and textbooks effective replacements for hands-on practical activities?

Findings from the
Practical Assessment in School Science (PASS) project

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About me

Alistair Moore

Research Fellow and Curriculum Specialist

University of York Science Education Group

Current research projects:

- Best Evidence Science Teaching (BEST)
- Science Beyond the Boundaries
- Practical Assessment in School Science (PASS)

Additional activities:

- Senior examiner for GCSE Biology
- Sit on the Curriculum Committee at the Royal Society of Biology
- Sit on the Research Committee at the Association for Science Education
- Member of the Biology Education Research Group (BERG)

Practical Assessment in School Science (PASS) project

Judith Bennett (PI)
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Three-year research project investigating the use of written examination questions to assess GCSE students' knowledge and understanding of practical work.

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PRACTICAL WORK

Practical work - at the heart of learning science

Practical work involves the collection of data through observation, investigation, experimentation and measurement.

“A learning activity in which students observe, investigate and develop an understanding of the world around them, through **direct, hands-on experience** of phenomena or manipulating real objects and materials.”

Resourcing Practical Science at Secondary Level (SCORE, 2013)

“I think it engages them, it breaks up the lesson for them… the more they enjoy it the more they're engaged with it the better their learning is because they're willing to put more effort into it.”

Teacher from Yorkshire (PASS Project, 2019)

Purposes of practical work

Understanding of scientific phenomena

Ability to use apparatus and follow procedures

Understanding of how science works

Increase motivation and engagement

(Millar & Abrahams, 2009; Holman, 2017)

Assessing practical work

- There is perhaps a lack of clarity as to what practical skills are and how they can, most effectively, be validly assessed (Abrahams, Reiss and Sharpe 2013)

- Particular practical competencies can only be assessed if students carry out hands-on practical work (e.g. following methods/instructions, using instruments/apparatus, making observations, carrying out entire investigations)

  Other knowledge and understanding of practical work can be assessed through a written test (e.g. planning investigations, representing data in tables/graphs/charts, interpreting/explaining/evaluating data)

  (Assessment of Performance Unit, Welford, Harlen and Schofield, 1985)

- **Direct assessment:** a student's competency at the manipulation of real objects is determined **as they manifest a particular skill**

  Indirect assessment: a student's competency is **inferred from data they have collected or their write-up** of practical work

  (Abrahams and Reiss, 2015)

Why does the assessment matter?

- High-stakes terminal assessment has a ‘backwash effect’ on what is done in lessons (Millar, 2013)
- Specifically it:
  - clarifies learning objectives
  - drives amount/type of practical work done in lessons

  (Millar, 2013; Abrahams et al, 2013; Erduran et al, 2020)
- Written assessment of practical skills can reduce the amount of hands-on practical work that is done (Bennett & Kennedy, 2001)

Why does the assessment matter?

- Therefore, it is crucial that the terminal assessment:
  - can discriminate effectively between students who have experienced different types and amounts of hands-on practical work

So that it incentivises the doing of:

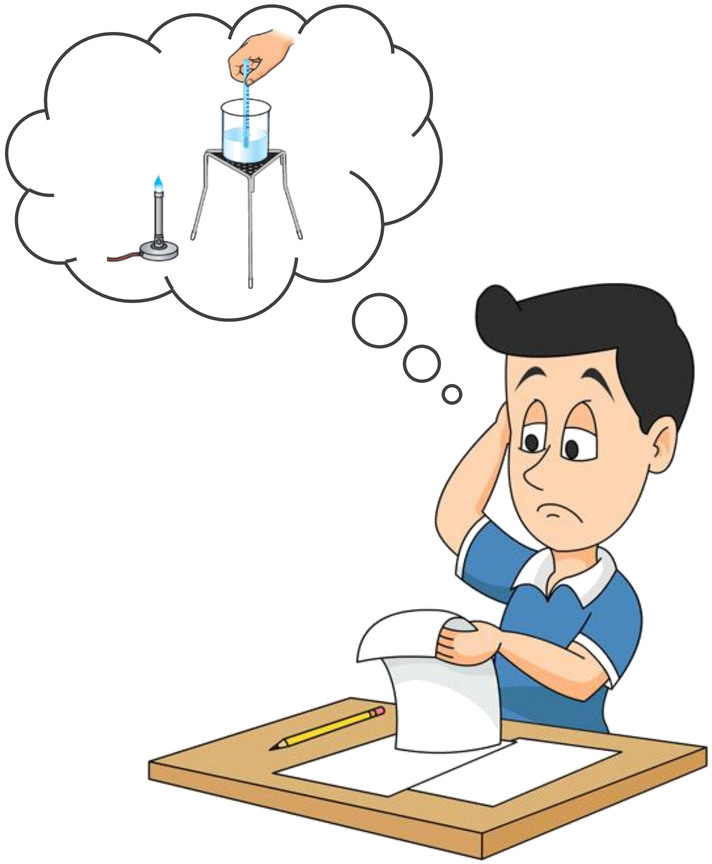
  - a variety of hands-on practical work
  - in sufficient quantities

Recent history of practical work in GCSE science

- Since 2016, GCSE students' knowledge and understanding of practical work wholly indirectly assessed through written examination questions

- Throughout the course, students must experience at least 8 practical activities, covering required practical techniques

- Written questions assessing knowledge and understanding of practical work make up 15% of the total GCSE marks (Ofqual, 2015)

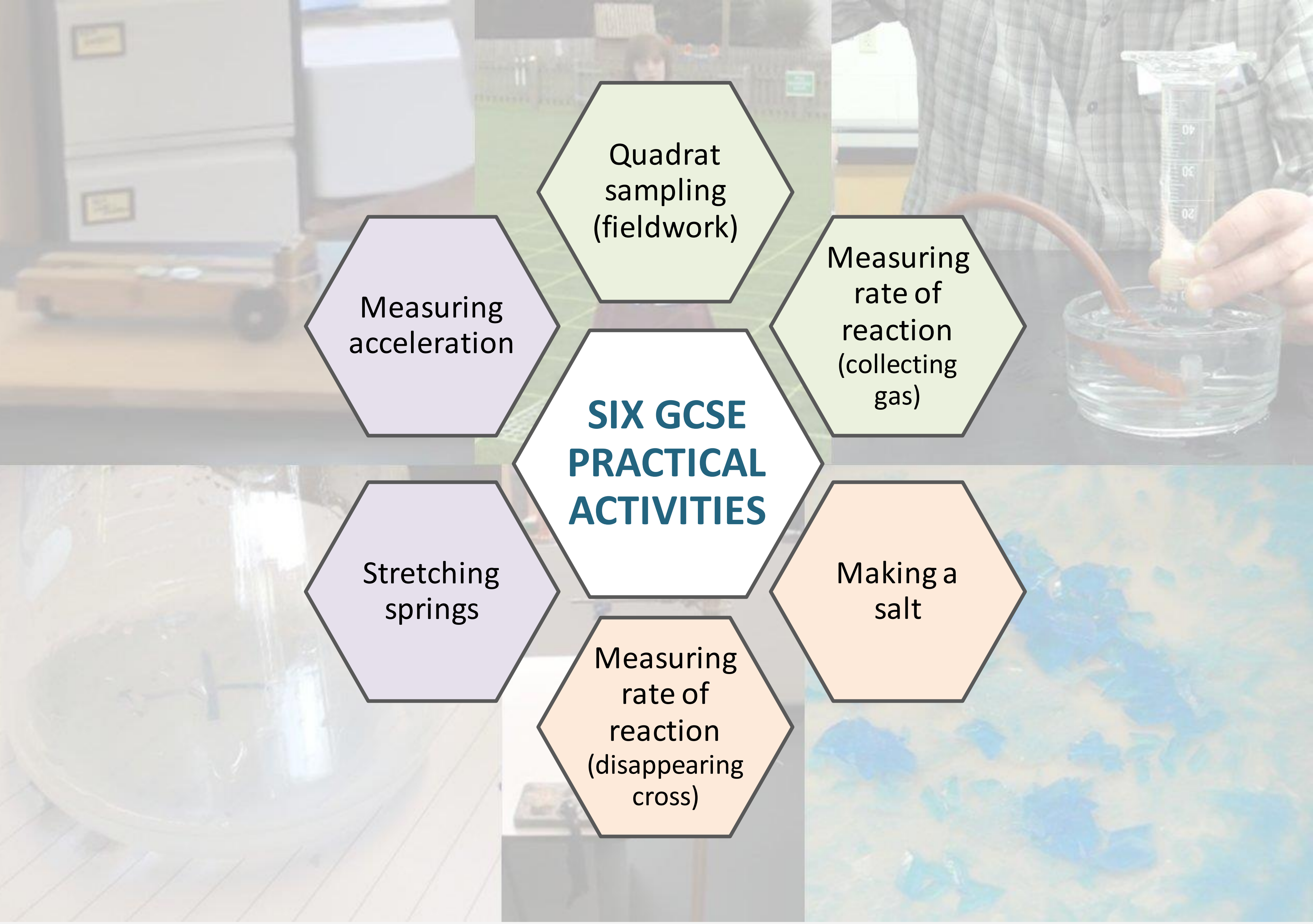


PRACTICAL ASSESSMENT IN SCHOOL SCIENCE (PASS) PROJECT

Practical Assessment in School Science (PASS) project

Research questions:

- Can written examination questions discriminate between students who have done different types and amounts of practical work?
- Are there any characteristic, generalisable features of questions that do discriminate effectively?
- What effects have the new assessment arrangements had on pedagogy?


SIX GCSE PRACTICAL ACTIVITIES
Quadrat sampling (fieldwork)
Measuring rate of reaction (collecting gas)
Making a salt
Measuring rate of reaction (disappearing cross)
Stretching springs
Measuring acceleration

Data collection

- Classes assigned into one of four different intervention groups for each practical activity:
  - hands-on practical activity
  - watching teacher demonstration
  - watching a video demonstration
  - reading about the practical activity in a form such as that presented in a textbook

- Mixed-methods approach to data collection:
  - **Quantitative data:** student performance on post-intervention test (GCSE examination-style practical questions)
  - **Qualitative data:** lesson observations, semi-structured interviews with teachers, and scrutiny of students' records of practical work

Part 1

Initials

1 Jess wants to investigate the population sizes of plants in an area of grassland.

She identifies 20 different plant species in the area.

The area measures 100 m x 50 m.

Describe a technique that Jess could use to estimate the population size of each of the plant species per m^2 of the grassland.

Include details of how Jess could take care to preserve the grassland and how she might process the data she collects.

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.... **[6]**

Initials

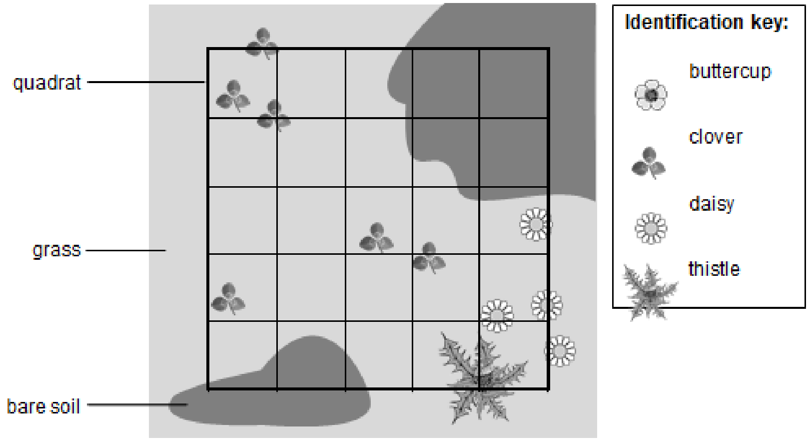
Part 2

1 Kai wants to measure the population sizes of different plant species on the sports field.

He will have to count the number of plants of each species in a sample of the field.

(a) He places a quadrat on the field.

The diagram shows what he observes.



(i) Kai writes down the rule he will use to count the number of plants of each species in the quadrat.

Count each plant that is at least half way inside the quadrat.

Use the diagram to complete the results table.

species	number of plants
buttercup	
clover	
daisy	
	1

[1]

(ii) Kai uses the following rule to count the number of squares in the quadrat that contain grass.

Count each square that is at least half covered by grass.

How many squares in the quadrat should be counted as containing grass?

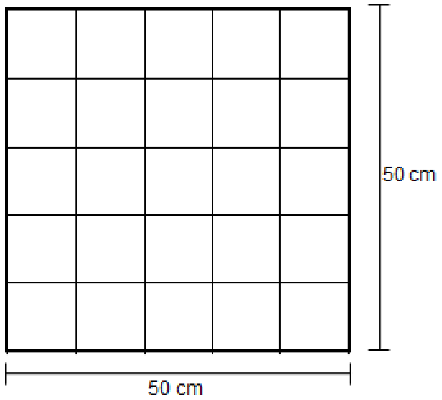
number of squares of grass .... **[1]**

(iii) Estimate the percentage cover of grass in the quadrat.

Show your working.

percentage cover of grass .... % **[2]**

(b) The quadrat measures 0.5 m x 0.5 m.



Kai collects data from a sample area of the field, as follows:

- He places the same quadrat in 10 different locations on the field.
- He counts and records the number of plants of each species in the quadrat in each location.

(i) What is the total area of Kai's sample in m^2?

Show your working.

sample area .... m^2 **[2]**

(ii) The total area of the field is 3000 m^2.

What percentage of the sports field was included in Kai's sample?

Show your working. Give your answer to 1 significant figure.

answer .... % **[3]**

(iii) The results from Kai's sample are shown in the table.

mean number of plants per quadrat				**mean % cover per quadrat**	
buttercup	**clover**	**daisy**	**thistle**	**grass**	**bare soil**
4	6	3	1	84	16

Kai placed each quadrat by walking around on the sports field and then choosing where to put the quadrat.

He concludes that in his sample:

- clover is the most abundant plant species (apart from grass)
- thistle is the least abundant plant species.

He is **not** confident that the conclusions from his sample apply to the whole field.

Explain how Kai could improve his method so that he could have more confidence in applying his conclusions to the whole field.

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.... **[4]**

Project timeline

Feb – Sep 2018
- Build understanding of current practice
- Develop interventions and tests

Oct 2018 – Sep 2019
- **Trial interventions with Year 10 students**
- **Data collection and analysis**

Sep – Oct 2019
- Refine interventions and tests

Oct 2019 – May 2021
- **Trial revised interventions with Year 10 students**
- **Data collection and analysis**

End of 2021
- Final report

Effects on practical work in science lessons

- **Before the pandemic:** a sense of practical work being 'squeezed out' of secondary science lessons
  - content-heavy curriculum
  - the move to assessment via written examination questions
- **During the pandemic:**
  - months of school closures and home/remote schooling
  - the examinations regulator is allowing students to observe teacher demonstrations rather than carrying out hands-on practical work (Ofqual, 2020)
- **Following the return to in-school teaching:** practical work competing for teaching time with, among other things
  - diagnosing and responding to issues in students' understanding
  - catching up on missed content
  - developing understanding of new material

QUANTITATIVE DATA ANALYSIS

Sample (first year of data collection)

- 1252 students in Year 10 (age 14-15) from schools across London and Yorkshire
- Classes assigned into one of four different intervention groups:
  - hands-on practical activity
  - watching teacher demonstration
  - watching a video demonstration
  - reading about the practical activity
- Groups balanced on class-level data on student characteristics:
  - predicted GCSE grades, gender, ethnicity, SEND, EAL and FSM, and years of teacher experience
  - Variety of school types, inc. academies, community schools and faith schools

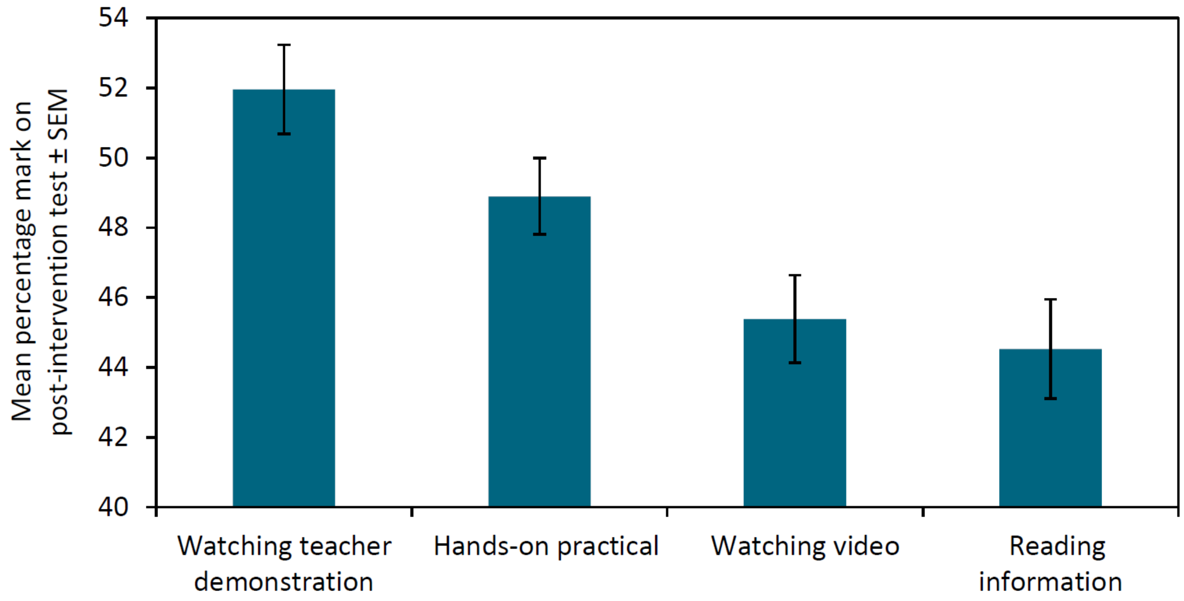
Quantitative analysis (first year)

- Compared differences in mean student scores for the four different intervention types, across the six practical activities (one-way ANOVA)

- Throughout the analysis, group data sets were checked for normality
  - The group data sets are of sufficient size for this to be unlikely to affect the outcome of a one-way ANOVA test
  - Kruskal-Wallis test for non-parametric data indicated the results of the one-way ANOVA test could be used with confidence

- Significant differences found with the one-way ANOVA were followed up with Tukey HSD post-hoc tests

Quantitative analysis (first year)



- The difference between teacher demonstration intervention and hands-on practical was not statistically significant ($p = 0.345$)
- Teacher demonstration gave a statistically significant higher mean percentage mark than watching a video ($p = 0.002$) and reading information about the practical ($p = 0.001$); both effect sizes were large.

Quantitative analysis (first year)

	Total mark %
Teacher demo.	52.0
Hands-on practical	48.9
Video	47.5
Written information	45.4

TD-V p=.002
TD-WI p=.001

Teacher interviews

- 12 face to face semi-structured interviews, audio-recorded and transcribed verbatim
- Sample:
  - 14 teachers
  - Even mix of female/male
  - Wide range of teaching experience from newly qualified to 35 years
  - Teaching in state-funded schools
  - Range of student attainment levels
- Thematic content analysis

Teacher interviews

“As I’m doing the demo, I’m explaining it to them, questioning them at the same time.”

“When you do the demonstration, obviously you’ve got your class and you’re getting them to think with the questioning.”

“[During the demonstration] we had a good discussion about what we were doing and why, and I think that allowed them to think.”

“If I want to really focus them and say, ‘Look, these are the key points’, I think demonstrating [is effective]. I can focus their minds and get them to think about the important bits of the practical and why they’re doing it.”

Good practice in a teacher demonstration

- Clear introduction explaining the aim of the practical activity, with an overview of what will be done and the key observations that will be made.
- Identifying steps in the procedure so that students could focus on the reasons for different procedures, or the ways these were carried out.
- **Questioning** about procedure and good practice that provided opportunity for **student involvement and discussion**.
- Taking opportunities to emphasises key points including:
  - Providing scenarios for students to ‘correct’ the teacher
  - Requiring students to notice and note key parts of practical procedure

Good practice in a teacher demonstration

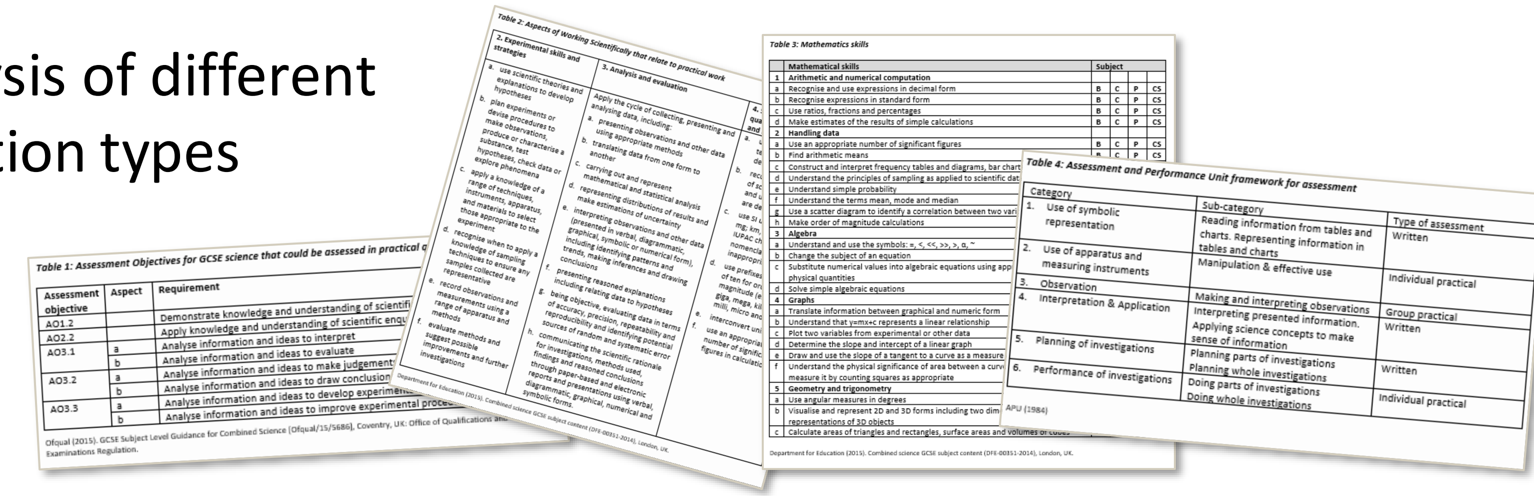
- Encouraging student observers to give a running commentary of the events.
- Encouraging thinking and predicting, including voting on what might happen.
- Sometimes measurements rehearsed before measuring for real.
- Sometimes, limited number of measurements taken, only until confident that students understood how to take them, then pre-prepared results used for analysis.
- Using the analysis part of the lesson to reflect on and review procedures through **small group discussion** about the experiment and results.

Headline messages: practical work in a COVID-19 world

- Students should be given opportunities to carry out hands-on practical work whenever possible
  - GL343: Guide to doing practical work during the COVID-19 Pandemic – Science (CLEAPSS, 2020)
  - Removal of hands-on practical work could disadvantage students who need to experience practical work first-hand in order to understand what is happening (e.g. VI and SEND) (Ofqual, 2020)
  - Hands-on practical work can increase student engagement
- If circumstances prevent hands-on practical work, schools should deliver **student-engaged** teacher demonstrations that include **purposeful discussion and questioning**.
- Reliance solely upon videos or textbooks is likely to disadvantage students in examinations.

Further analysis

- Analysis of different question types

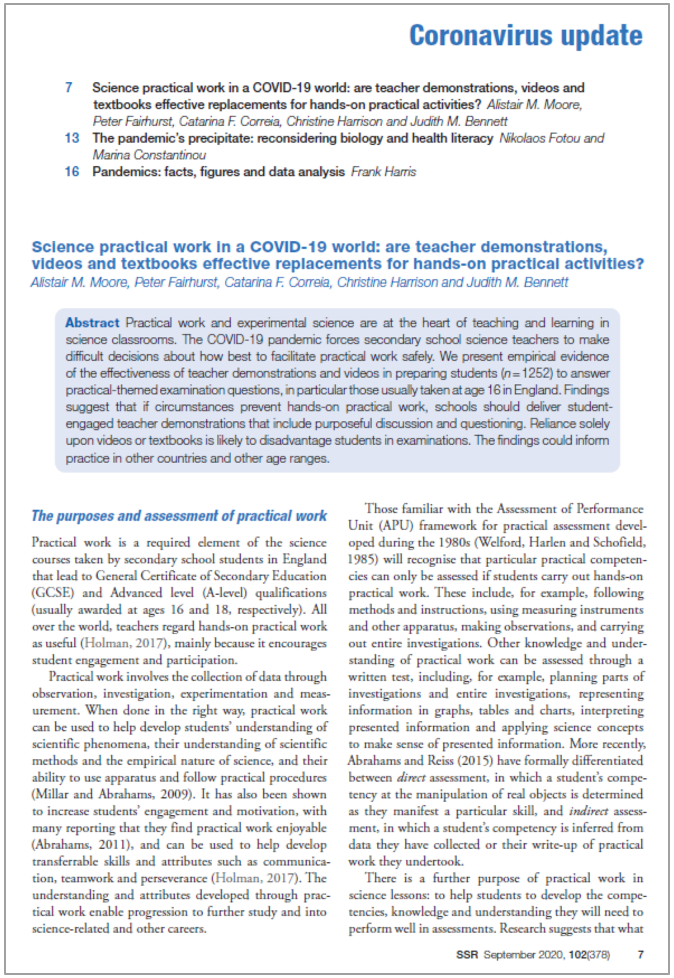


- More detailed comparisons will be possible with more data
  - Which particular types of question distinguish well between students?
  - What are the specific, generalisable characteristics of questions supported by hands-on practical work?

Further reading

Moore, A., Fairhurst, P., Correia, C., Harrison, C. and Bennett, J. (2020) Science practical work in a COVID-19 world: are teacher demonstrations, videos and textbooks effective replacements for hands-on practical activities? *School Science Review*, 102 (378), 7-12.

Open-access at:
https://www.ase.org.uk/system/files/SSR_September_2020_007-012_Moore.pdf



Coronavirus update

Science practical work in a COVID-19 world: are teacher demonstrations, videos and textbooks effective replacements for hands-on practical activities?

Alistair M. Moore, Peter Fairhurst, Catarina F. Correia, Christine Harrison and Judith M. Bennett

Abstract Practical work and experimental science are at the heart of teaching and learning in science classrooms. The COVID-19 pandemic forces secondary school science teachers to make difficult decisions about how best to facilitate practical work safely. We present empirical evidence of the effectiveness of teacher demonstrations and videos in preparing students ($n = 1252$) to answer practical-themed examination questions, in particular those usually taken at age 16 in England. Findings suggest that if circumstances prevent hands-on practical work, schools should deliver student-engaged teacher demonstrations that include purposeful discussion and questioning. Reliance solely upon videos or textbooks is likely to disadvantage students in examinations. The findings could inform practice in other countries and other age ranges.

The purposes and assessment of practical work

Practical work is a required element of the science courses taken by secondary school students in England that lead to General Certificate of Secondary Education (GCSE) and Advanced level (A-level) qualifications (usually awarded at ages 16 and 18, respectively). All over the world, teachers regard hands-on practical work as useful (Holman, 2017), mainly because it encourages student engagement and participation.

Practical work involves the collection of data through observation, investigation, experimentation and measurement. When done in the right way, practical work can be used to help develop students' understanding of scientific phenomena, their understanding of scientific methods and the empirical nature of science, and their ability to use apparatus and follow practical procedures (Millar and Abrahams, 2009). It has also been shown to increase students' engagement and motivation, with many reporting that they find practical work enjoyable (Abrahams, 2011), and can be used to help develop transferrable skills and attributes such as communication, teamwork and perseverance (Holman, 2017). The understanding and attributes developed through practical work enable progression to further study and into science-related and other careers.

Those familiar with the Assessment of Performance Unit (APU) framework for practical assessment developed during the 1980s (Welford, Harlen and Schofield, 1985) will recognise that particular practical competencies can only be assessed if students carry out hands-on practical work. These include, for example, following methods and instructions, using measuring instruments and other apparatus, making observations, and carrying out entire investigations. Other knowledge and understanding of practical work can be assessed through a written test, including, for example, planning parts of investigations and entire investigations, representing information in graphs, tables and charts, interpreting presented information and applying science concepts to make sense of presented information. More recently, Abrahams and Reiss (2015) have formally differentiated between *direct* assessment, in which a student's competency at the manipulation of real objects is determined as they manifest a particular skill, and *indirect* assessment, in which a student's competency is inferred from data they have collected or their write-up of practical work they undertook.

There is a further purpose of practical work in science lessons: to help students to develop the competencies, knowledge and understanding they will need to perform well in assessments. Research suggests that what