Assessment of practical work in A Level (and GCSE) sciences

Time to try harder?

John Holman

Outline of my talk

1. Why is practical work so important in science education?
2. What is happening now in schools and universities?
3. What has gone wrong?
4. Some lessons from overseas
5. How to put it right?
    1. Ofqual's proposals
    2. Are there better ways?
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John Dee Performing an Experiment Before Queen Elizabeth I

Surprising Science

- I searched for words indicating surprise among 30,133,141 abstracts of English-language scientific papers indexed in the Scientific Citation Index (SCI) and 8,151,087 English-language academic articles in the Social Sciences and Arts and Humanities citation indexes.

- The word ‘surprising’ appears 12 times more frequently in the natural sciences than in standard English and 1.3 times more frequently than in social sciences, arts and humanities.

Michal Jasienski, Poland. Letter to Nature, 2006

Practical work is essential to science education

It is not just ‘nice to have’

Is it just a good way of learning science ideas?

"The fundamental purpose of practical work in school science is to help students make links between the real world of objects, materials and events, and the abstract world of thought and ideas."

Does Practical Work Really Work? A study of the effectiveness of practical work as a teaching and learning method in school science
Ian Abrahams and Robin Millar

“The fundamental purpose of practical work in school science is to help students make links between the real world of objects, materials and events, and the abstract world of thought and ideas.”

Is that all?

Science Learning Centres practical work survey (secondary teachers)

– 1339 responses from science teachers and technicians (March 2010)

Top reasons for doing science practical work

- Helping learners to understand scientific concepts (88%)
- Making phenomena more real i.e. linking theory to practice (84%)
- Helping learners to develop skills e.g. observation, using equipment (82%)
- Motivating learners (81%)
- Helping learners to develop understanding of scientific enquiry (80%)

Purposes of science practical work (assumptions for this seminar)

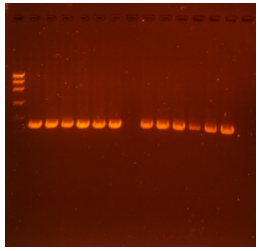
- To support learning of knowledge and concepts
- To develop technical skills *e.g. using a microscope or a burette with precision*
- To develop understanding of 'the scientific approach'
- To motivate and enthuse.

Authentic Biology at Tapton School, Sheffield

Year 13 students learn how to do a PCR reaction. Later they will do it themselves to amplify genes selected from zebra fish. This is part of research project on heart disease with the University of Sheffield.

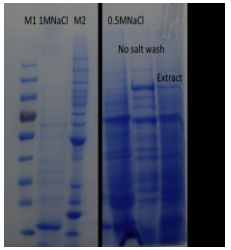
Research Enhanced Active Learning
In the Innovation Labs, Liverpool Life Sciences UTC

Genomic PCR Y12 Labs



Croda-sponsored
Synthetic Biology Project

Mealworm Proteomics
Royal Society funded Y10 Labs



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University teachers' views on the practical skills of science undergraduates (1)

45 staff from bioscience, chemistry and physics departments of 11 universities.

- 97% felt that new undergraduates were not well equipped with the necessary lab skills.
- 57% said that lab skills in new undergraduates had declined in past 5 years (compared to 29% and 37% reporting a decline in knowledge and understanding respectively).
- Universities are adapting their courses because of the decline in practical skills.

Laura Grant Associates for The Gatsby Foundation, 2011

University teachers' views on the practical skills of science undergraduates (2)

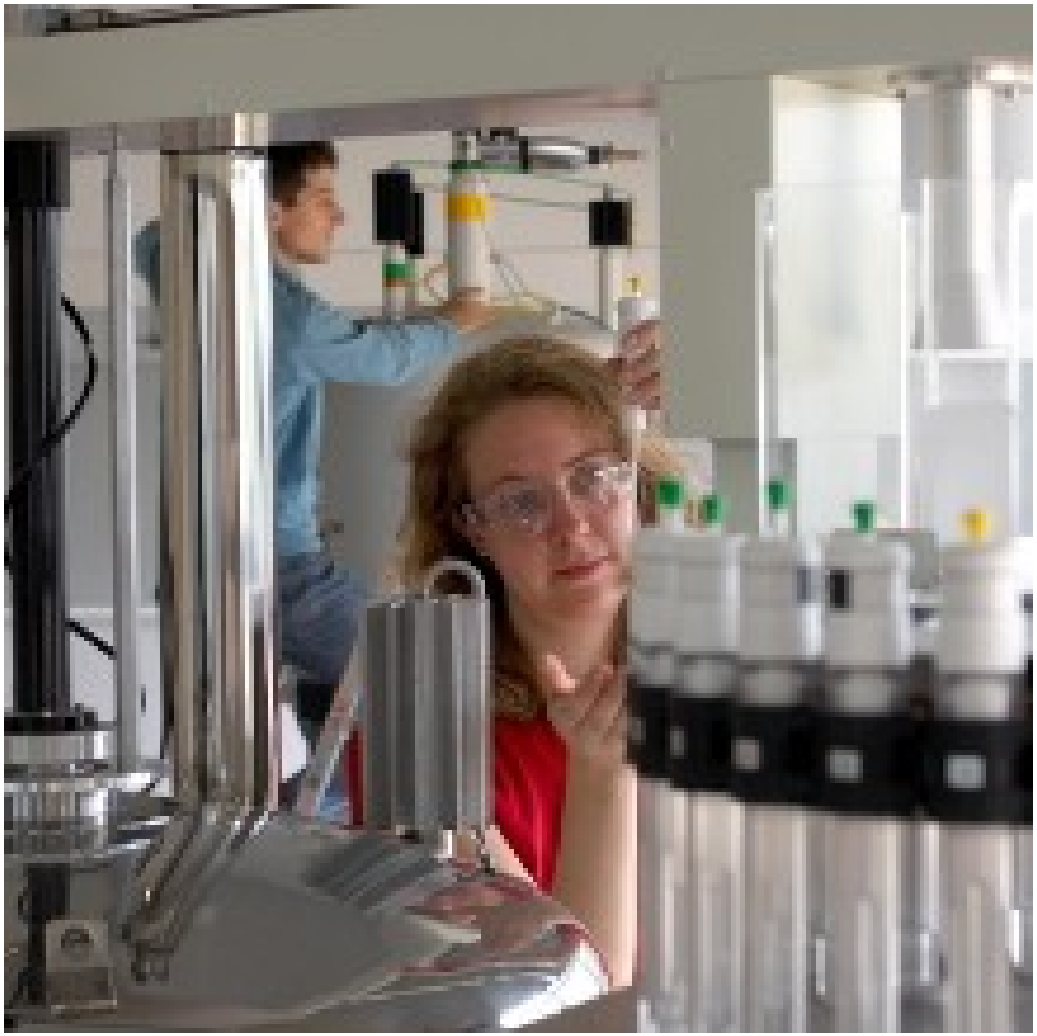
- University staff say feedback from students suggests schools and colleges are covering less practical work, with some students claiming they have done no practical work at all.
- Even when students reported experience of hands-on work at school, they tended to have a limited set of skills relevant to undergraduate experiments and were overly mark-oriented.
- However, students who had completed an extended investigation as part of their A level appeared better equipped for university practical work.

Laura Grant Associates for The Gatsby Foundation, 2011

What do my first year undergraduates say?

Survey of 90 first year Chemistry undergraduates at the University of York, June 2014

Students at York spend a full day per week in the chemistry labs.



Survey of 90 first year Chemistry undergraduates at York

- 57% from an English school with sixth form
- 34% from an English FE or sixth form college
- 9% from overseas.

Thinking back to your pre-university studies, how frequently did you do hands-on practical chemistry?

More than 2 times a week	**1%**
1 - 2 times a week	**22%**
Once a week	**34%**
Once every two weeks	**24%**
Once a month	**13%**
Less than once a month	**4%**

75% did practical chemistry once a week or less.

Rank the following the following types of practical chemistry based on how much time you spent on them

Answer from 0 to 2, where 0 = least time; 2 = most time.

Extended practical investigation(s) lasting a week or more

Experiments linked to the theory you were studying

Controlled assessments that counted to your exam grade

Rank the following the following types of practical chemistry based on how much time you spent on them

Answer from 0 to 2, where 0 = least time; 2 = most time.

Extended practical investigation(s) lasting a week or more	**0.24**
Experiments linked to the theory you were studying	**1.47**
Controlled assessments that counted to your exam grade	**1.24**

How well do you think each of the following types of practical would prepare you for studying chemistry at university?

Answer 0 = not at all; 1 = fairly well; 2 = very well.

Extended practical investigation(s) lasting a week or more

Experiments linked to the theory you were studying

Controlled assessments that counted to your exam grade

How well do you think each of the following types of practical would prepare you for studying chemistry at university?

Answer 0 = not at all; 1 = fairly well; 2 = very well.

Extended practical investigation(s) lasting a week or more	**1.27**
Experiments linked to the theory you were studying	**1.38**
Controlled assessments that counted to your exam grade	**0.81**

How well do you think your pre-university experience of practical chemistry prepared you for practical chemistry at university?

Not at all

Poorly

Moderately well

Very well

How well do you think your pre-university experience of practical chemistry prepared you for practical chemistry at university?

Not at all	**5%**
Poorly	**35%**
Moderately well	**51%**
Very well	**9%**

What do my first year undergraduates like about practical work at university?

- Independence
- Longer experiments
- Contextualised experiments
- More challenging experiments
- Modern equipment
- Practical work that is linked to theory.

What do undergraduates say?

“Doing the practical helps cement the theory in your mind.”

What do undergraduates say?

“
Students should get as much hands-on experience as possible instead of just watching the teacher do an experiment.

Important to do practical, as it plays a big part at university.

”

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What has gone wrong with the current system of assessment of science practical?

At both GCSE and A level:

- Under the pressure of accountability, schools are ‘coached within an inch of their life on how to pass an exam’. The pressure on individual teachers to award high practical grades is almost irresistible.
- So marks in controlled assessment are bunched at the top end, giving poor discrimination.
- At the same time, controlled assessments focus on a narrow, reproducible set of experiments done under artificial conditions.
- Schools spend a lot of time preparing for and carrying out controlled assessments, at the expense of richer practical work.

What do undergraduates say?

“A lot of the time in my experience, students are told exactly what to write to achieve a certain grade.”

What do undergraduates say?

“Most teachers cheat and those that don’t will deny their students the highest grades.”

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Lessons from overseas* (1)

Schools in the UK have

- Facilities for practical work as good as anywhere else I've seen in the world – and often better.
- Technician support better than anywhere else in the world.

So we should be in a position to do great practical work in science.

**From visits in 2013 to schools in Hong Kong, Finland, Netherlands, Germany, Ontario and previous visits to schools in Japan, USA, Shanghai, France.*

Lessons from overseas (2)

Summative assessment by teachers is less controversial in most countries in Europe, North America and Australasia than in the UK.

See for example, NAHT's Commission on Assessment, chaired by Lord Stewart Sutherland, February 2014, and OECD's Reviews on Evaluation and Assessment Frameworks.

But it is not without problems ….

Lessons from overseas (2)

Summative assessment by teachers is less controversial in most countries in Europe, North America and Australasia than in the UK. **But ….**

Teachers need training to give them the skills and confidence to be expert assessors*

There need to be effective systems for inter-school moderation.

How will these changes come about if summative assessment is taken away from teachers?

**Black et al,* Validity in teachers' summative assessments

Assertion

If teacher assessment can win public trust, it is a more reliable and valid way to assess students' capabilities than examinations.

"….. rests on the argument that teachers can sample the range of a pupil's work more fully than can any assessment instruments devised by an agency external to the school. This enhances both reliability (because it provides more evidence than is available through externally-devised assessment instruments) and validity (it provides a wider range of evidence)."

Mansell, W., James, M. & the Assessment Reform Group (2009) Assessment in schools. Fit for purpose? A Commentary by the Teaching and Learning Research Programme. London: Economic and Social Research Council, Teaching and Learning Research Programme.

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Why is it so important to assess practical skills in A level and GCSE sciences?

- Practical skills are integral to sciences.
- If practical skills are on the specification, they should be assessed.
- The users of GCSE and A level qualifications – employers and universities – need to know about their applicants' practical as well as theoretical skills.

Can practical skills be validly assessed through written questions* only?

- It may be more valid for some skills (eg planning an investigation) than others (eg reading instruments with precision).
- However good the written question, teachers will always find ways to coach students to do well in them without necessarily doing the experiment.
- **We need more evidence before we can answer this robustly – but we need help with this from Awarding Organisations.**

* 'Written questions' here includes computer-based assessments.

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Ofqual's proposals for A level

- Direct assessment of practical skills will no longer be included in a candidate's A level grade.
- Instead, candidates will get a pass/ fail statement ('endorsement') about practical skills, based on a list of 12 specified experiments.

Ofqual's proposals for A level: possible outcomes for teaching and learning

Optimistic

- Could lead to a wider range of practical work being carried out in schools and colleges
- Could lead to more practical work as schools and colleges are released from the shackles of controlled assessment.

Pessimistic

- Could lead to a narrowing of practical work onto just 12 experiments
- Could lead to less practical work being carried out if schools and colleges conclude it is irrelevant to university entry.

We just can't tell, but history suggests we should be cautious.

What do undergraduates say?

The way that practical skills are assessed at A level is changing. The teacher will no longer give students a mark for practical skills which counts towards their A level grade. Instead, they will get a pass/ fail statement for their practical skills which will be recorded on their A level certificate. Their A level grade will be based on written questions in a final exam only. What effect do you think this will have on practical work in A level chemistry?

No effect

Will encourage better practical work

It will make practical work deteriorate

What do undergraduates say?

The way that practical skills are assessed at A level is changing. The teacher will no longer give students a mark for practical skills which counts towards their A level grade. Instead, they will get a pass/ fail statement for their practical skills which will be recorded on their A level certificate. Their A level grade will be based on written questions in a final exam only. What effect do you think this will have on practical work in A level chemistry?

No effect	**11%**
Will encourage better practical work	**8%**
It will make practical work deteriorate	**81%**

What do undergraduates say?

“Practicals may become more diverse and mean that teachers do not just do practicals for assessment but actually for learning chemistry.”

What do undergraduates say?

“ …….. there is a chance that this may encourage some teachers to do more interesting experiments based on what their students want.

”

What do undergraduates say?

“Having a pass-fail statement means that students will only put in just the amount of effort needed to pass.”

What do undergraduates say?

“I did very little, only the necessary assessed, if this was removed it is likely I wouldn’t do any practical. I feel many schools would be like this.”

What do undergraduates say?

“ If marks for practicals can be inflated, so can the rate of pass grades so it does not solve the original problem. ”

Views from the universities

- If practical coursework is not assessed as part of the A level, then schools may not see the value in teaching it as it is expensive to run, so we risk students applying to university without having had any practical experience. Students are likely to come to university having been taught, not how to do practical work, but how to avoid it. [Imperial College]
- There is a real danger that moving the practical component out of the A level mark will mean that practical work will be downgraded. [York]
- Sends wrong message to students re importance of practical chemistry in their degree programme [Manchester]
- … if these skills are not assessed, many teachers will not give students the chance to develop them, and senior managers in schools will deprioritise practical work, reducing resourcing and ultimately eliminating practical work as a key component in science lessons. [Southampton]

What about AS?

And for GCSE?

June 2013:

- Our subject experts concluded that 'written work alone cannot reliably assess all the skills candidates are asked to demonstrate within the qualification' *Review of Controlled Assessment in GCSEs, June 2013*
- We therefore propose that the demonstration of science practical skills should be assessed other than by exam, marked by teachers and contribute to the overall grade. *GCSE reform consultation, June 2013, Ofqual*

April 2014:

- In light of the concerns about our initial proposal for GCSE science skills and the developments in A level science, we have decided to do further work and consult again before deciding how practical science skills should be assessed in GCSEs. *An update on reforms being made to GCSEs, April 2014, Ofqual*

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Better ways to assess practical skills

What can we learn from

- Past experience?
- Other countries?
- Other subjects?
- Other settings (eg universities)?

We want to research this, but we need help from Awarding Organisations.

Two models

1. **The Ideal**
2. **The Robust**

Two models

1 **The Ideal**: an extended individual practical project, marked by the teacher and moderated within a group of schools.

The ability to design/plan an experiment, … collect the data, … and evaluate the experiment is the essence of good scientific practice, and in the long distant past, the majority of chemistry degree newcomers had these skills to some level. Since 2010, these skills seem to have largely evaporated, aside from those students who have done the OCR Salters A-level where they have to do a project which involves the use of each of those skills. [University of Southampton]

Two models

2. **The Robust**: a carousel of short experiments carried out under exam conditions, invigilated by a teacher from another school, marked by teachers and moderated within a group of schools.

As being piloted in Ireland for the new Leaving Certificate after extensive international research. Practical skills make up 30% of the final grade.

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Believe in a better world

In which

1. The curriculum and assessment frameworks would be stable and would change no more frequently than every five years.
2. The accountability framework within which schools and colleges operate would not rely so heavily on examination performance.
3. Teachers would be trusted to carry out assessments which contribute significantly to public qualifications.

Believe in a better world

In which

1. The curriculum and assessment frameworks would be stable and would change no more frequently than every five years.

Could we get cross-party agreement to an arrangement whereby the curriculum and assessment are determined by independent subject panels, perhaps convened by professional bodies?

Believe in a better world

In which

2. The accountability framework within which schools and colleges operate would not rely so heavily on examination performance.

Could schools be accountable against a wider range of metrics such as students' destinations, students' and parents' satisfaction, practical work opportunities, extra curricular activity … as well as examination performance?

Netherlands' *Framework for Responsibility*

Vensters voorverantwoording

20+ Indicators Framework for Responsibility

General	Quality	Educational
• *About this school*	• Students' satisfaction	• School Plan
• *Number of students*	• Parents' satisfaction	• Care Plan
• *Market share*	• Supplying and continuation schools	• Networks
• *Profile and sector choice*	• School climate and safety	• Teaching time
	• External evaluations	• Students' features
Results	**Operations**	**Practical education**
• *Pass Rate*	• *Finance*	• Diplomas and (branch) certificates
• *Exam Results*	• *Educational Staff*	• Placement of students
• *Flow and outflow*	• Absenteeism	• Constancy of placement
• *Depart from school*	• Training Expenses	
	• *Number of students / staff*	

Source data: DUO/Inspectorate, OCW
Source data : schoolboards, schools

Believe in a better world

In which

3. Teachers would be trusted to carry out assessments which contribute significantly to public qualifications.

To achieve this, teachers would need to be professionally trained in assessment, and there would need to be robust systems of inter-school moderation.

But the direction of travel is now away from this rather than towards it.

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Practical science research consortium

- The Gatsby Charitable Foundation
- The Nuffield Foundation
- The Wellcome Trust.

Practical science research consortium

A three-year programme of work supporting practical science in UK schools by improving the quality of assessment.

1 Produce influential, independent evidence on the state of practical science in UK schools and colleges

a) Monitor changes in practical science in schools and colleges through an independent annual survey of schools and teachers, building on the SCORE resourcing and Wellcome Trust Governors' benchmarks.
b) Research the attitudes and practices of HE in relation to practical skills of new undergraduates, using previous Gatsby work as a benchmark.

2 Provide useful information for curriculum and qualifications developers on the most appropriate content and assessment for practical science in GCSEs and A levels

a) Produce more definitive lists of important practical skills in the sciences, complementing the work of the professional bodies' curriculum committees.

b) Identify and promote use of best practice in written assessment of practical skills, informing community-wide consensus on written questions with high validity and low possibility of theory-only preparation for exams.

3 Propose new models of assessing practical skills in science for discussion and development among the UK education community

a) Identify and evaluate better approaches to assessment of practical skills, including international perspectives and current practice in Higher Education, building from previous Gatsby work and consulting experts in the Nuffield network of education researchers.

Where is the expertise?

In schools

In universities

In the Awarding Organisations.

Last word

The people in this seminar can instigate our programme of research, but it is the people outside of the room – the teachers and the students – who have most to gain from it.