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Exploring the validity of virtual labs for assessing science practical skills

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What I will cover

- Background and context
- Research aim and method
- Findings
- Benefits of virtual labs for assessment, teaching and learning
- Conclusion
- What next?....

Background and context

Background and Context

- Various methods to assess science practical skills – differing impact on teaching and learning
- Direct vs indirect assessment
- Direct assessment through physical lab work not always possible
  - Logistics, resources, regional variations (restrictions)
- Validity of indirect assessment methods?
- Alternative to practical (ATP) (written paper) not ideal – no manipulation of equipment. Effect on practicals done in the classroom?

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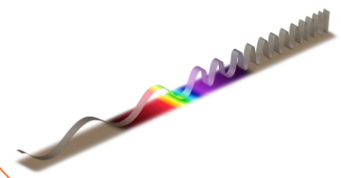

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Cambridge Pathway

Science Practical skills

- IGCSE 0620 and 0625

Practical assessment

All candidates take one practical paper from a choice of two.

Paper 5: Practical Test		Paper 6: Alternative to Practical
1 hour 15 minutes		1 hour
40 marks		40 marks
All items are compulsory		All items are compulsory
This paper tests assessment objective AO3	OR	This paper tests assessment objective AO3
Candidates will be required to do experiments in a laboratory as part of this test		Candidates will not be required to do experiments as part of this test
Externally assessed		Externally assessed

Questions in the practical papers are structured to assess performance across the full grade range.

Notes for use in qualitative analysis are provided for both Paper 5 and Paper 6.

The Practical Test and Alternative to Practical:

- require the same experimental skills to be developed and learned
- require an understanding of the same experimental contexts
- test the same assessment objective, AO3.

A Level 9701 and 9702

- **Paper 3 Advanced Practical Skills**
  Paper 3 is a timetabled, laboratory-based practical paper focusing on the experimental skills of:
  - manipulation, measurement and observation
  - presentation of data and observations
  - analysis, conclusions and evaluation.

- **Paper 5 Planning, Analysis and Evaluation**
  Paper 5 is a timetabled, written paper focusing on the higher-order experimental skills of:
  - planning
  - analysis
  - drawing conclusions
  - evaluation.

Direct vs Indirect?

	Direct (DAPS)	Indirect (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 undertake
How is the assessment undertaken?	Observations of students as they undertake a piece of practical work – marks awarded based on questions about the results	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 the expertise at the practical skills that will be assessed	• More straightforward for those that 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

Reproduced from Reiss, Abrahams and Sharpe (2012)

Challenges faced by schools for direct assessments

- Logistics
- Resources
- Regional and Jurisdiction variations, regulations and restrictions

Virtual labs

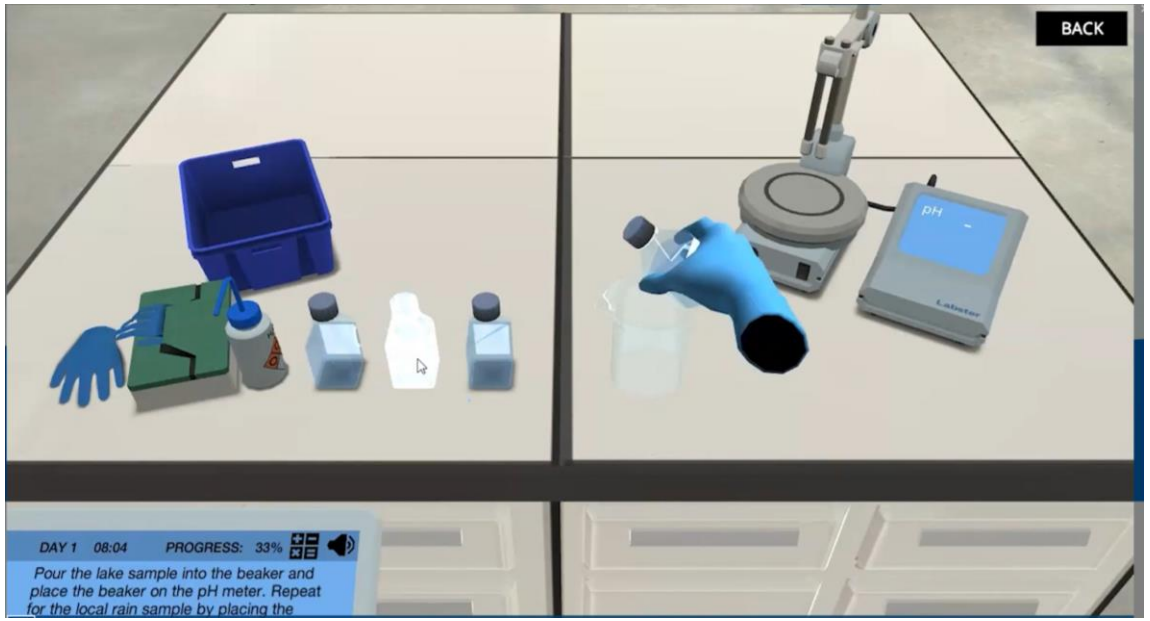
Could virtual labs be another option (other than the ATP)?

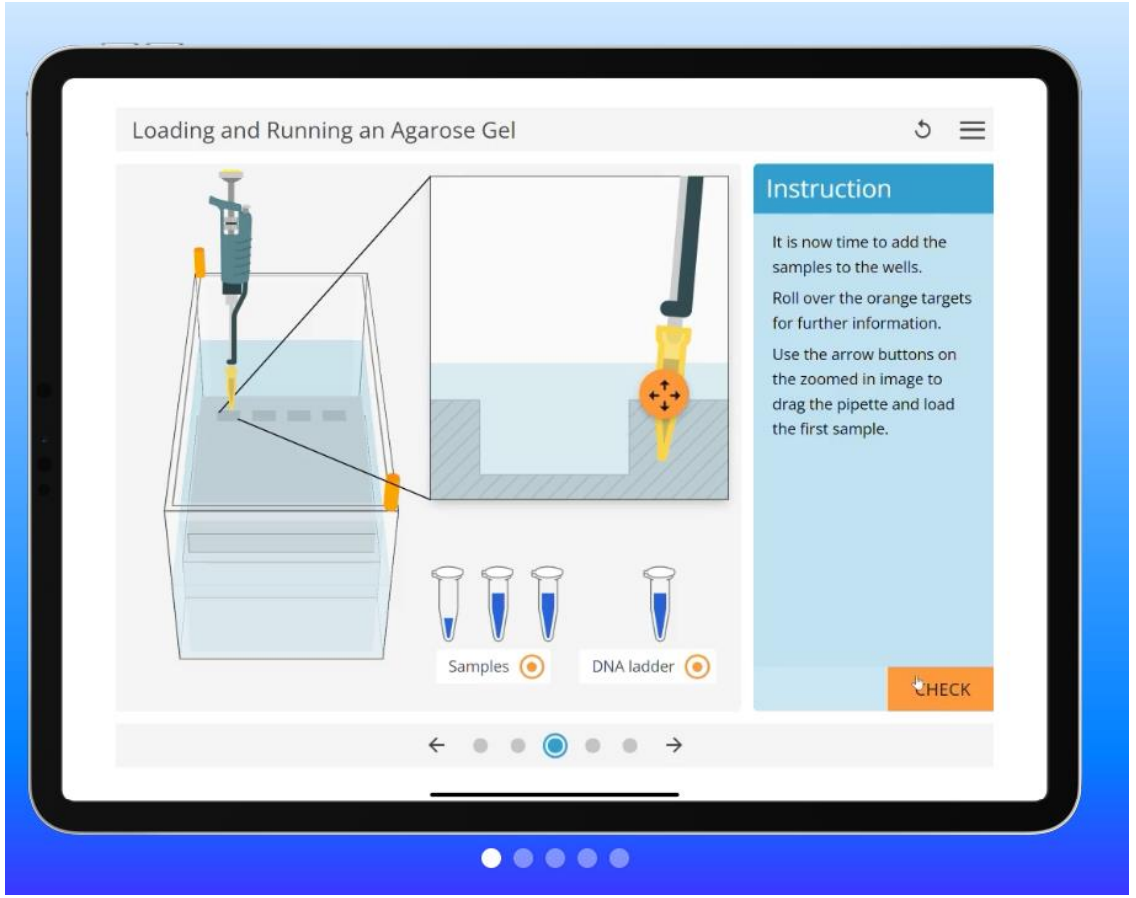
Can take many forms

Computer simulations – attempt to replicate experiments on screen

Known for their use in teaching and learning – what about assessment?

Examples of virtual lab software





Research aim and method

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To explore the potential validity of virtual labs for the summative assessment of science practical skills (as an alternative to ATP)

Used Crooks et al. (1996) chain model as a theoretical framework

Explore threats, benefits and opportunities for the validity of virtual labs in summative assessment

Literature gathered from databases, screened and coded.

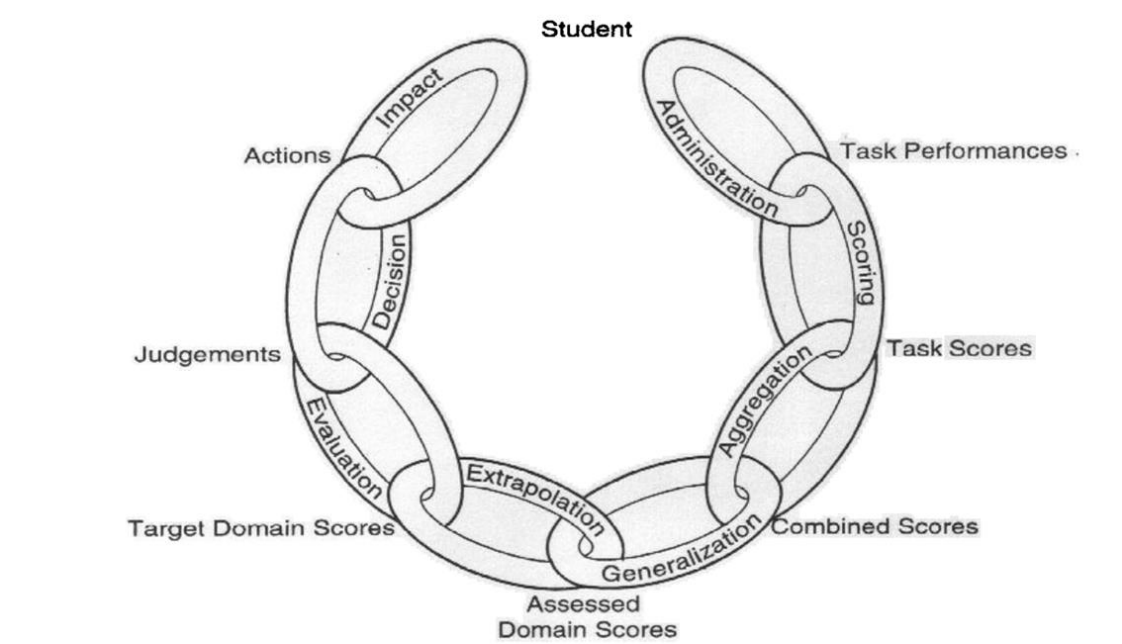

FIG. 1. A model of educational assessment for use in the validation and planning of assessments.

Crooks et al. (1996) chain model of validity

- Assessment depicted in eight stages, likened to links of a chain
- Range from administration through to impact
- Guidance to identify possible validity threats in each link.

Our Findings

Key validity issues

Administration	Generalisation, extrapolation and evaluation	Impact
Cognitive demand • screen could be more demanding to process Computer malfunctions / technical issues Inequality in ICT equipment / literacy Construct underrepresentation • certain skills not included due to digital administration Software development is time consuming and expensive • linear rather than open ended experiences Less planning and predicting in a virtual environment • less need to think before acting Risk of assessing digital skills over the intended skills Digital design decisions can be tricky • e.g., different ways to represent effervescence.	Construct underrepresentation • students are not learning use of specialised equipment and hands-on work. Lack of tactile and kinaesthetic learning. Construct-irrelevant variance – computer skills ⇩ Cannot say that students have developed all the relevant science practical skills (although they will likely have developed a subset of relevant practical skills).	Digital fatigue due to increased screen time? Barrier to practical work / devaluing of physical practical skills? Impact on future progression • lab skills needed in university or workplace Need for learning with physical objects to learn to self-construct abstract concepts Expense of software development could lead to fewer practicals being offered Poor quality software leads to an oversimplified view of scientific enquiry.

Benefits of virtual labs for assessment, teaching and learning

Benefits of virtual labs for assessment (comparison to the ATP)

Access

Increased access to practical science

Potentially more realistic, immersive experience.

Engagement

Enjoyable and engaging for students and teachers.

Affordances of digital environment

E.g., clocks and progress indicators.

Improved assessment of practical skills

Potentially improve assessment of practical skills over the ATP (indirect evidence)

Support preparation for future real lab work - doing a virtual lab before a real experiment improved students' execution of the experiment and reduced anxiety (Darrah et al., 2014; Reyes et al., 2024)

"evoke cognitive reactions …comparable to those elicited by physical surroundings" (Reyes et al., 2024)

Promote skills like collecting and assembling apparatus, operating lab equipment and experiencing lab procedures (albeit virtually) (Ambusaidi et al., 2018)

Benefits of virtual labs for teaching and learning

Teaching and learning

Repetition: Students can repeat experiments multiple times.

Guidance: Guide students through complex processes and provide links to the theory behind them.

Speeding up processes: Processes sped up for learning purposes.

Safe and risk free: Explore concepts without being exposed to dangerous materials or intricate equipment. Access to different topics and practicals normally impossible.

Enhance understanding: of scientific concepts – depends on design, integration and learning context.

Microscopic phenomena: Illustration of microscopic phenomena.

Remote learning: Facilitate remote learning and teaching, allow students to practice at home.

Personalisation and feedback: Potential for personalisation and rich immediate formative feedback.

Conclusion

Conclusion

- Virtual labs have the potential to assess a subset of science practical skills
- Because they require manipulation of equipment (albeit virtually), they potentially represent an improvement over written examination (ATP)
- But – key issues and threats were identified and need careful consideration
- Areas for future research recommended.

What next?....

Future research

- More research on the predictive value for real lab work and the skills assessed
- Analysis of currently available software capabilities
- Mapping of practicals and assessing their suitability for virtual labs
- Principles of best practice for designing and implementing virtual labs for assessment purposes.

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Thank you!

Key issues to think about

- Quality and design of software – can current software provide what we need?
- Impact on physical practical skills (negative washback)?
- Practicalities
- Appetite (market)
- Would it work for all practicals?
- Which age group is best?
- What other ways can we implement technology into science assessment that is more authentic?
- Career paths – why are students choosing to study science?