Integrated instructions in practical work
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Steve Jones and Bob Worley, CLEAPSS
Practical work – a hard ask for students

Information overload in a lab environment (from Education in Chemistry, 1982)


Working and Long Term Memory

Atkinson–Shiffrin memory model (1968) / Baddeley (1992) for WM rather than STM
Working Memory

Where you ‘consciously think’

Limited capacity

If it is overloaded, task completion/learning is impeded

Long-term Memory: Schema

Working Memory

Long Term Memory

Encoding
Retrieval

Schema – ‘the alphabet’
Long term Memory: A science schema

Heat 100 cm³ of water to 50°C

Cognitive Load Theory (CLT)

What is happening in the Working Memory? Three types of load...

**Intrinsic**
- complexity of concepts
- inter-relatedness of ideas

**Extraneous**
- complexity of the instructional materials
- external influences

**Germane**
- building the mental models (schema) about the concepts
Cognitive Load Theory (CLT)

Example: Titration

An intrinsically complex activity
- New equipment
- Recalling prior knowledge
- Making and understanding observations
- Accurate measurement
- Calculation
Good instructional sequencing

- Recap neutralization and indicators
- Simple (gravimetric) titration
- Introduce new equipment
- Simulation of titration
- Simple volumetric titration
- Data analysis – lots of examples
- Strong and weak acids
- Develop investigative skills

Extraneous load - electrolysis

- Spillages in setting up the test tubes
- Connecting powerpack and getting it working
- Collecting enough gas
- Getting the test tubes filled
- Getting the boss and clamp right
Simplifying equipment

Split attention – a demonstration

Time how long it take you to:

Write out all the numbers from 1 to 26 in order, left to right.

---THEN---

Write out all the letters from A to Z in order, left to right.

Make a note of how long that took.
Split attention – a demonstration

Without looking at your previous work...
Time how long it takes you to:

Write out A1, B2, C3 through to Z26, in order, left to right.

Compare with your previous time.

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A model of memory

[Diagram with labeled components: central executive, visuospatial sketchpad, episodic buffer, phonological loop, semantics (general knowledge), episodic (events), procedural (how to) with pointers to Working memory ‘Fluid systems’ and Long term memory ‘Crystallised systems’]

Extraneous load – the split-attention effect

Figure 2: The spatial contiguity principle: (a) reducing extraneous load by integrating labels with visualisation; (b) extraneous load is increased when labels are not integrated with visualisation

Rebecca Torrance Jenkins, Using educational neuroscience and psychology to teach science Part 1, SSR December 2017

Integrated Instructions – Deschri et al

1. Obtain four clean, dry test tubes. Pour 1.0 mL samples of sodium thiosulfate solution (Na₂S₂O₃) into the tubes as follows:
   - Tube 1: 0.25 M Na₂S₂O₃
   - Tube 2: 0.50 M Na₂S₂O₃
   - Tube 3: 1.0 M Na₂S₂O₃
   - Tube 4: 2.0 M Na₂S₂O₃

Integrated Instructions

1. Add 2 cm$^3$ of 0.2 M sodium chloride solution to a test tube.
2. Add 5 drops of 0.5 M nitric acid to the same test tube.
3. Add 5 drops of 0.1 M silver nitrate solution to the same test tube.
4. Make and record your observations.

Split attention in practical work

- Add 20 cm$^3$ of the 0.5 M sulfuric acid to the 100 cm$^3$ beaker. Heat carefully on the tripod with a gentle blue flame until nearly boiling.
- When the acid is hot enough (just before it starts to boil), use a spatula to add small portions of copper(II) oxide to the beaker. Stir the mixture gently for up to half a minute after each addition.
- When all the copper(II) oxide has been added, continue to heat gently for 1 to 2 minutes to ensure reaction is complete. Then turn out the Bunsen burner. It may be wise to check (using pH or litmus paper) that no acid remains. If the acid has not been hot enough, excess acid can co-exist with copper oxide.
- Allow the beaker to cool slightly while you set up Stage 2.

Stage 2

- Place the filter funnel in the neck of the conical flask.
- Fold the filter paper to fit the filter funnel, and put it in the funnel.
- Gently swirl the contents to mix, and then pour into the filter paper in the funnel. Allow to filter through.
- A clear blue solution should collect in the flask. If the solution is not clear, and black powder remains in it, you will need to repeat the filtration.

Stage 3 (optional)

- Rinse the beaker, and pour the clear blue solution back into it. Label the beaker with your name(s). Leave the beaker in a warm place, where it won’t be disturbed, for a week or so. This will enable most of the water to evaporate. Would fill with toxic fumes.
- Before all the water has evaporated, you should find some crystals forming on the bottom of the beaker. Filter the solution. Collect the crystals from the filter paper onto a paper towel.

Integrated-instructions in practical work

1. 1.8–2.0g copper oxide. Add half and swirl, wait 1 minute, add the other half.
2. 15cm³ sulfuric acid – wait 2 minutes
3. Half fill with just boiled water
4. Filter copper sulfate solution (max 3 min)
5. Remove funnel, then gently heat solution (half-blue) for 3 minutes – DO NOT BOIL DRY
6. Pour filtered heated copper sulfate into the evaporating dish; observe for 5 minutes

Student practical work

[Image of bowls containing blue liquid]
Making integrated instructions

Improving practical work with integrated instructions

Do your students struggle to follow written instructions?

https://eic.rsc.org/feature/improving-practical-work-with-integrated-instructions/3009798.article
Making integrated instructions

1. Add 1.8-2.0 g copper(II) oxide. Add half and swirl, wait 1 minute, add the other half.

2. chemix.org is also proving popular.


Microscale neutralisation

Questions:

- Describe the sequence of observations – what happened first, second etc.
- What observations did you make that solutions were formed?
- What observations did you make that showed a neutralisation has occurred?
Distillation of crude oil

Questions:
- Describe the change in temperature you observed as you heated the crude oil.
- What observations did you make that showed distillation was occurring?
- What was the purpose of the tube between the boiling tube and the collection test tube?

Properties of crude oil fractions

Questions:
- Describe how the viscosity changed between the fractions.
- Describe how the ease of setting light to the fractions changed between the fractions.
- Describe how the odour changed between the fractions.
Student task completion and learning

- All students completed all practical
- On average only one in-practical question per two students
- Most questions referred back to instructions
- Most students gave at least ‘partially appropriate’ answers to ‘observation’ questions
- Variable responses to ‘reason for practical step’ questions

Students’ opinions of integrated instructions

- All students ranks all practical 1-3 on the Likert scale for ‘how easy was the practical’
- Students like the ‘clarity’ of the instructions – they could ‘see’ what they were supposed to so.
- “It helped me do the practical without asking the teacher”
- “They gave me more confidence because I knew I was doing the right thing”
My reflections at the time

- Allowed me to have a better overview of the whole lab – less time dealing with ‘thoughtless questions’
- Students quickly started self/peer correcting by reference to instructions – increased independence
- Gave a useful visual cue during and after the practical

Journal of Chemical Education article

Design and Evaluation of Integrated Instructions in Secondary-Level Chemistry Practical Work
David J. Paterson

https://pubs.acs.org/doi/10.1021/acs.jchemed.9b00194
Chemistry ‘Required’ Practical (AQA)


Physics ‘Required’ Practicals (AQA)
Year 9: Traditional vs Integrated

PRACTICAL: Catalyst of the reaction between zinc and sulfuric acid
Purpose: To compare the rate of reaction of zinc with sulfuric acid under the influence of temperature on the reaction rate.

Method:
1. Obtain the necessary equipment and reagents.
2. Set up two identical reaction setups.
3. Determine the temperature difference between the setups.
4. Record the rate of reaction for each setup.

Diagram:

Year 12: Traditional vs Integrated

PRACTICAL: Finding the formula of unknown crystals
Purpose: To experimentally determine the empirical formula of an unknown compound.
Method:
1. Obtain the necessary equipment and reagents.
2. Determine the mass of the compound.
3. Record the results of the experiment.

Diagram:
Student opinions of different practical types

Understanding – How easy/hard did you find it to understand the practical instructions?
Carryout – How easy/hard did you find it to carry out the practical work?
Confident – How confident did you feel during the practical work?
Successful – How successful did you feel at the end of the practical?
Helpful – How helpful was the practical in your learning?

Student comments on different practical types

Year 9: Traditional
- ☺ Very simple and understandable.
- ☹ There was a lot of information compacted into a line/sentence which made it difficult to read at first.

Year 9: Integrated
- ☺ I loved how easy they were.
- ☹ (none)

Year 12: Traditional
- ☺ I liked about the practical instructions. It is very clear to show how to place the equipment and the description of method is easy to understand.
- ☹ I disliked the layout because when you read it in a rush you tend to get confused and read the wrong words and miss information. I like how the measurements were in bold.

Year 12: Integrated
- ☺ The layout was clear. It was detailed but not in a complicated way.
- ☹ They make it easy to understand what to do but not why. It means you can just do it and not have to think at all.
Other comments from Twitter

Chris Goodman @Chrgyrooty - Jan 2
Replying to @dave2004b and @theAEE
I used Diffusion/Red Dyes with my Y7s. It worked beautifully, a quick expt even when carried out by 11/12 yr olds. I asked my daughter what she remembered. It showed that thing diffusion. The closest drops changed colour more quickly because the gas diffused to them first.

Sarah @MmeSarah - Jan 2
Replying to @dave2004b and @theAEE
I've used your integrated instructions and shared them with my department. Once they are explained to students, the students can work much more independently and make fewer mistakes in the methods. I've used the style and @ChemLab to create my own too.

Alistair Gittner @rgittner - Jan 2
Replying to @dave2004b @MmeSarah and 2 others
In section 6, I used these with the lower prior attainment students. The Democritean moment was realised that they are great for the higher prior attaining too.

Louise Cess @busierCass - Jan 2
I'm sure you know my thoughts on them - I use them for all practicals. It's alleviated that constant questioning of what to do next, they're more focussed. I have a large version on the wall and print smaller ones for their books. I particularly like the II and the microchem ones.

Becky-Anne S @beckyschem - Jan 2
Replying to @dave2004b and @theAEE
I've loved using them for required practices! Once we're done we annotate around it with definitions for keywords, safety information, expected results and why you do certain things to think about what you could be asked questions on. Then often go on to attempt exam q. inc B&Q

Dr. Nik Reveke @nikreveke - Jan 2
Replying to @dave2004b and @theAEE
I find that the students are much lessedly & just get on with the practical. They don't come up & ask what to do next every five minutes. I think they do with written instructions. They might come closer to the board to check for a second then just carry on.

PhysioMumma4yza @PhysioMumma - Jan 2
Replying to @dave2004b and @theAEE
I really like the idea and use them when I can but struggle to put them together for certain phys practicals where it's not focused on one piece of equipment. Measure this, time that, push this... watch for x to happen... it gets messy when I try to design the instructions.

PRS Science @PRS_Science - Jan 2
Replying to @PhysioMumma @dave2004b and 2 others
We use these for pretty much all of our required practicals combined with slow practical methodology, annotating for hazards, risks etc. Students engage more and produce more useful work. Only criticism is when lines crossing over lead to ambiguity.

Dr Kriete Turner @Dr_kriete - Jan 2
Replying to @dave2004b and @theAEE
I tried them with a mixed Y9 class, the practical was still a disaster... not sure you want to hear that, or that my sample of one class is in any way representative.

Jessica Field @JessieOgdan - Jan 2
Replying to @dave2004b @Wish83 and @theAEE
I think they're great! We use them when doing practical but also as retrieval prompts for revision - give the images and students produce methods/ retrieve anything else they can around the RP

Louise Cess @busierCass - Jan 2
Replying to @busierCass @dave2004b and @theAEE
I feel they're more confident with the steps and my Y10 groups (RA of 8-11) work together to compete opposed to one taking the lead and doing all the work.
End notes

Plenty more at dave2004b.wordpress.com
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