Integrated-instructions in practical work

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Staff and students at Aldenham School

Steve Jones and Bob Worley, CLEAPSS
Practical work – a hard ask for students

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

Practical work – the pyramid model

![Pyramid Model Diagram]

Fig. 3. Class teaching often begins with a single idea which is elaborated (3a). Often it seems that, in practical work, the pyramid is inverted (3b), obscuring the point we are trying to make.

Different approaches in class work and practical work (Johnstone and Wham, from Education in Chemistry, 1982)

Working and Long Term Memory

Atkinson–Shiffrin memory model (1968)
A model of memory

- **Central executive**
- **Episodic buffer**
- **Phonological loop**
- **Visuospatial sketchpad**
- **Semantics (general knowledge)**
- **Episodic (events)**
- **Procedural (how to)**

**Working memory**
- ‘Fluid systems’

**Long term memory**
- ‘Crystallised systems’

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Working Memory

Where you ‘consciously think’

Limited capacity

If it is overloaded, task completion/learning is impeded
Working Memory – a test

Remember as many of the following as you can:

149  219  181  945  199  720  102  019
Working Memory – a test

Write down as many as you can remember.

How many did you manage?
Working Memory – a second test

Remember as many of the following as you can:

1492  1918  1945  1997  2010  2019
Working memory – a second test

Why was it easier the second time?

- Bigger ‘chunks’ of information
- Use schema (pre-existing knowledge) – famous dates.
- Relies on prior knowledge – the more you know, the easier it is to learn!

After Piaget 1923; Bartlet 1932
Long-term Memory: Schema

Schema – ‘the alphabet’

Working Memory

Long Term Memory

Encoding

Retrieval
### Cognitive Load Theory (CLT)

What are they thinking about in the Working Memory?

<table>
<thead>
<tr>
<th>Category</th>
<th>Details</th>
</tr>
</thead>
</table>
| **Intrinsic** | • complexity of concepts  
               • inter-relatedness of ideas |
| **Extraneous** | • complexity of the instructional materials  
                     • external influences |
| **Germaine** | • building the mental models (schema)  
                     about the concepts |
Cognitive Load Theory (CLT)

Total Cognitive Load = Intrinsic Load + Extraneous Load + Germane Load

Fixed

Manage with good instructional sequencing

Reduce with good instructional design

Maximise this!

https://www.researchgate.net/publication/269112838
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

http://www.rsc.org/learn-chemistry/resources/screen-experiment/titration
Extraneous load - electrolysis

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

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.
Split attention – a demonstration

One person writes; the other times.

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

Same person writes; same person times; without looking at the previous piece of paper:

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

Make a note of how long that took. Compare with your previous time.
Split attention in practical work

a Add 20 cm³ of the 0.5 M sulfuric acid to the 100 cm³ beaker. Heat carefully on the tripod with a gentle blue flame until nearly boiling.
b 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.
c 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.
d Allow the beaker to cool slightly while you set up Stage 2.

Stage 2

e Place the filter funnel in the neck of the conical flask.

f Fold the filter paper to fit the filter funnel, and put it in the funnel.

g Make sure the beaker is cool enough to hold at the top. The contents should still be hot.

h Gently swirl the contents to mix, and then pour into the filter paper in the funnel. Allow to filter through.
i 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)

j 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.

k 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 – 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.
Integrated-instructions in practical work

1. Half fill with just boiled water

2. 15 cm³ sulfuric acid
   - wait 2 minutes

3. 1.8-2.0g copper oxide. Add half and swirl, wait 1 minute, add the other half.

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
## Data collection

<table>
<thead>
<tr>
<th>Questions</th>
<th>Evaluation</th>
<th>Response (thinking of)</th>
</tr>
</thead>
<tbody>
<tr>
<td>What observation(s) did you make that showed you a chemical reaction had occurred?</td>
<td>Overall, how easy/hard did you find the practical (circle one number)</td>
<td>1 very very easy</td>
</tr>
<tr>
<td>What was the purpose of step 5 – gently heating the solution for 2 minutes?</td>
<td>How did the instructions help you <strong>understand</strong> what you were doing?</td>
<td></td>
</tr>
<tr>
<td>Describe the purpose of step 6.</td>
<td>How did the instructions help your <strong>confidence</strong> in completing the practical?</td>
<td></td>
</tr>
</tbody>
</table>
Early data

- Year 9 teaching group (18 students)
- Completed in 22 ± 5 minutes
- 23 student questions (12 required additional guidance)

“[The instructions] were clear, direct and the annotations helped to show what exactly we should do.”

“The pictures helped my confidence. I could visualise what I was doing.”
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 ‘helicopter’ view 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
Other integrated instructions
bit.ly/integratedinstructions

Biology – food tests
(R. Kirsten, Aldenham School)

Chemistry – electrolysis
(H. Lord, Haslingden High School)

Physics – density
(B. Cook)
GCSE Chemistry Practicals

Making integrated instructions

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

Making integrated instructions

https://eic.rsc.org/feature/improving-practical-work-with-integrated-instructions/3009798.article
<table>
<thead>
<tr>
<th>EQUIPMENT</th>
<th>INSTRUCTIONS</th>
<th>FLOW</th>
<th>PICTOGRAMS</th>
<th>IN LESSON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consider what the minimum required equipment is</td>
<td>Use clear numbering</td>
<td>Try to arrange instructions clockwise or anticlockwise</td>
<td>Use of 'eyes' to direct observation</td>
<td>Project the diagram on screen</td>
</tr>
<tr>
<td>Minimum text necessary</td>
<td></td>
<td></td>
<td>Use of 'clocks' to indicate timings</td>
<td>Issue paper copies to all students</td>
</tr>
<tr>
<td>Use of arrows to direct movement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use tick boxes so students can track their progress</td>
<td></td>
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</tr>
</tbody>
</table>
Now...

- Have a look at a couple of traditional vs integrated instructions.
- Annotate your copies – good points / constructive criticism.
- Any questions...
End notes

Plenty more at dave2004b.wordpress.com
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