Enhancing Undergraduate Science Laboratories

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Why Laboratory Work?

- Expensive – *staff, demonstrators, materials, accommodation*
- Time consuming – *planning, marking*
- How many physical science graduates actually become bench scientists?
- How much learning and understanding is gained?
- Are students given much credit for their laboratory work?
- Laboratory work was initially introduced to train skilled technicians.
- What if there were no physical science laboratories?
- The science education literature provides lots of attempts to change laboratory practice.
- Overview of this research will be covered.

What do Laboratory Practicals Offer?

- Principle aims:
  - Manipulative skills – *hand skills and 'autopilot'*
  - Observational skills – *detection threshold*
  - The ability to interpret experimental data - *understanding*
  - The ability to plan experiments – *problem solving*
- Affective aims:
  - Interest and enjoyment in the subject
  - A feeling of reality for the phenomena talked about in the theory

Reviewed in Johnstone and Al-Shuaili (2001)

Aims of Laboratory Work

Making science real

- Bringing chemistry to life
- Students get to see, touch and handle chemicals and equipment
- Data gathering and testing theoretical models

The methods of science

- Gain answers from the physical world by means of interpretation of experimental data

Intellectual skills

- Posing questions and understanding theoretical models
- Models of chemistry made more tangible

Personal skills

- Team working, planning, time management, discussion and debate
- Positive attitudes and stronger motivation to move onto more demanding tasks

Practical skills

- Safety and handling instruments

Preparing for the world of work

- About 30% of chemical undergraduates become bench chemists
- Experimental skills, managing time and risk
- The nature of precision
- World is where issues are faced, analysed and solved

Modified from Carnduff and Reid (2003)

Types of Laboratories

Style	Descriptor		
	Outcome	Approach	Procedure
Expository	Predetermined	Deductive	Given
Inquiry	Undetermined	Inductive	Student generated
Discovery	Predetermined	Inductive	Given
Problem-based	Predetermined	Deductive	Student generated

Expository: Most common, Lower order cognitive skills, verification of knowledge already obtained

Procedure (Expository): To obtain the *correct* results

Inquiry: Final year research project

Problem-based: Time consuming, costly, higher order cognitive skills

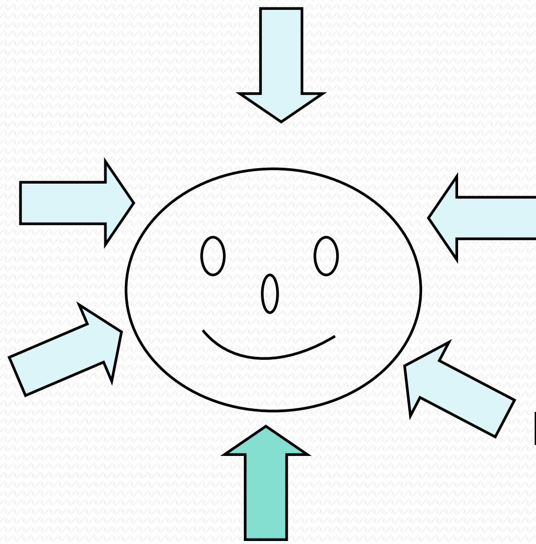
Domin (1999)

Information Load

Apparatus names and materials to be recognised and associated

Skills to be recalled

Theory to be recalled



New written instructions

New skills to be learned

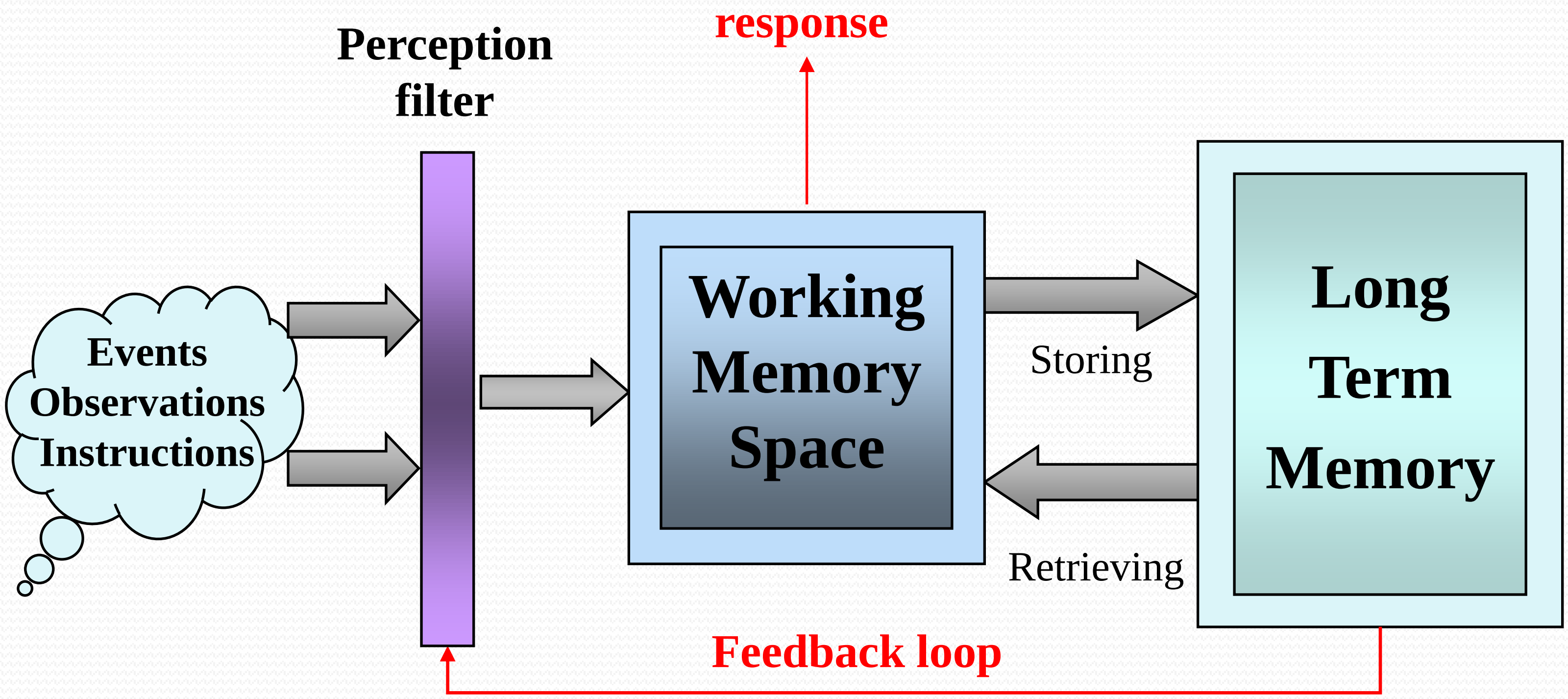
Input from actual experiment

Unstable overload results in recipe following and poor learning may occur.

Modified from Johnstone and Wham (1982)

An Information Processing Model

- A mechanism and framework for change



An Information Processing Model

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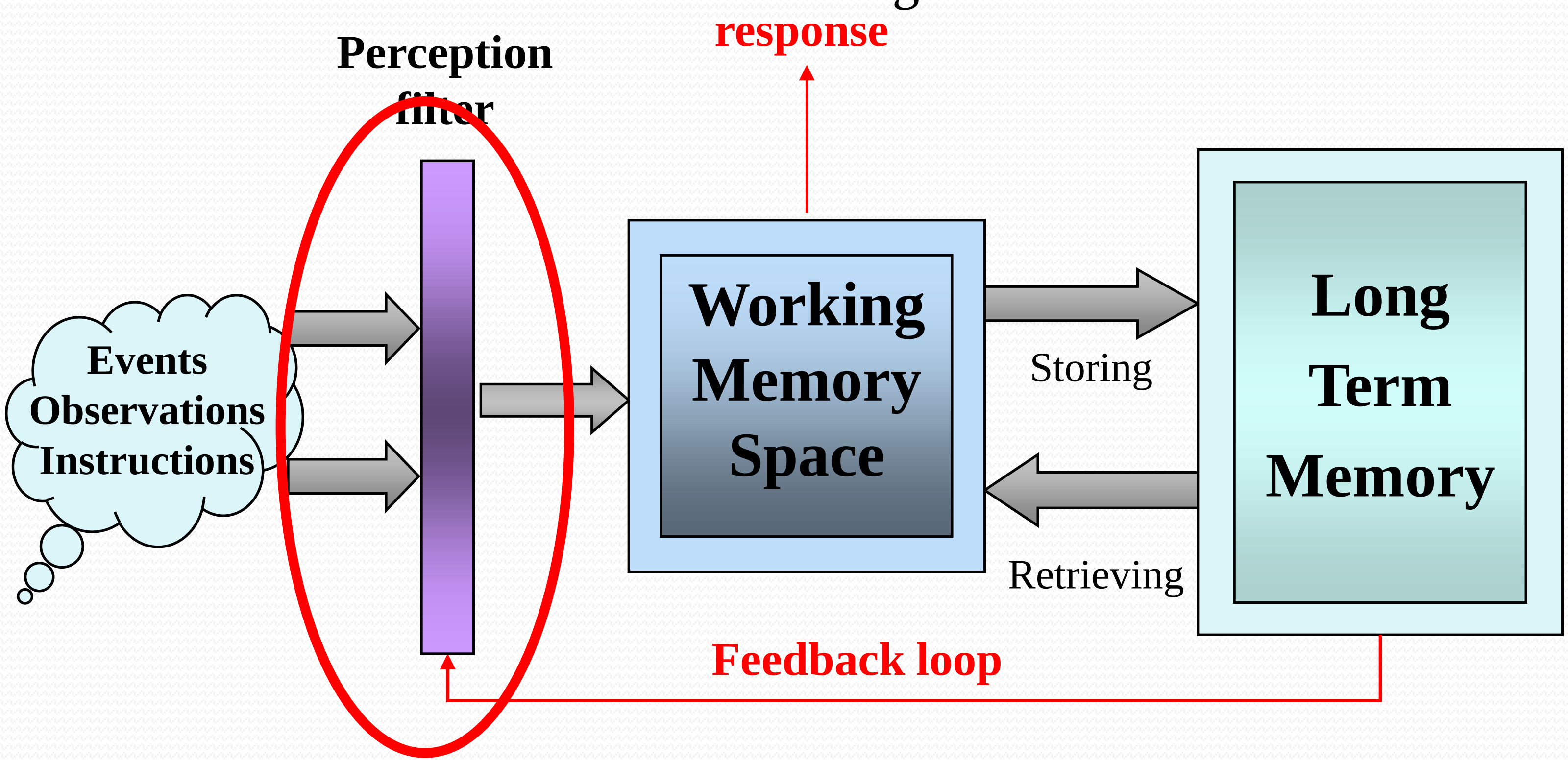

For each new laboratory experiment, the disembedding ability of the learner may not be clear. Differences in the novice and the expert experimenter.

Modified from Johnstone *et al* (1994)

An Information Processing Model

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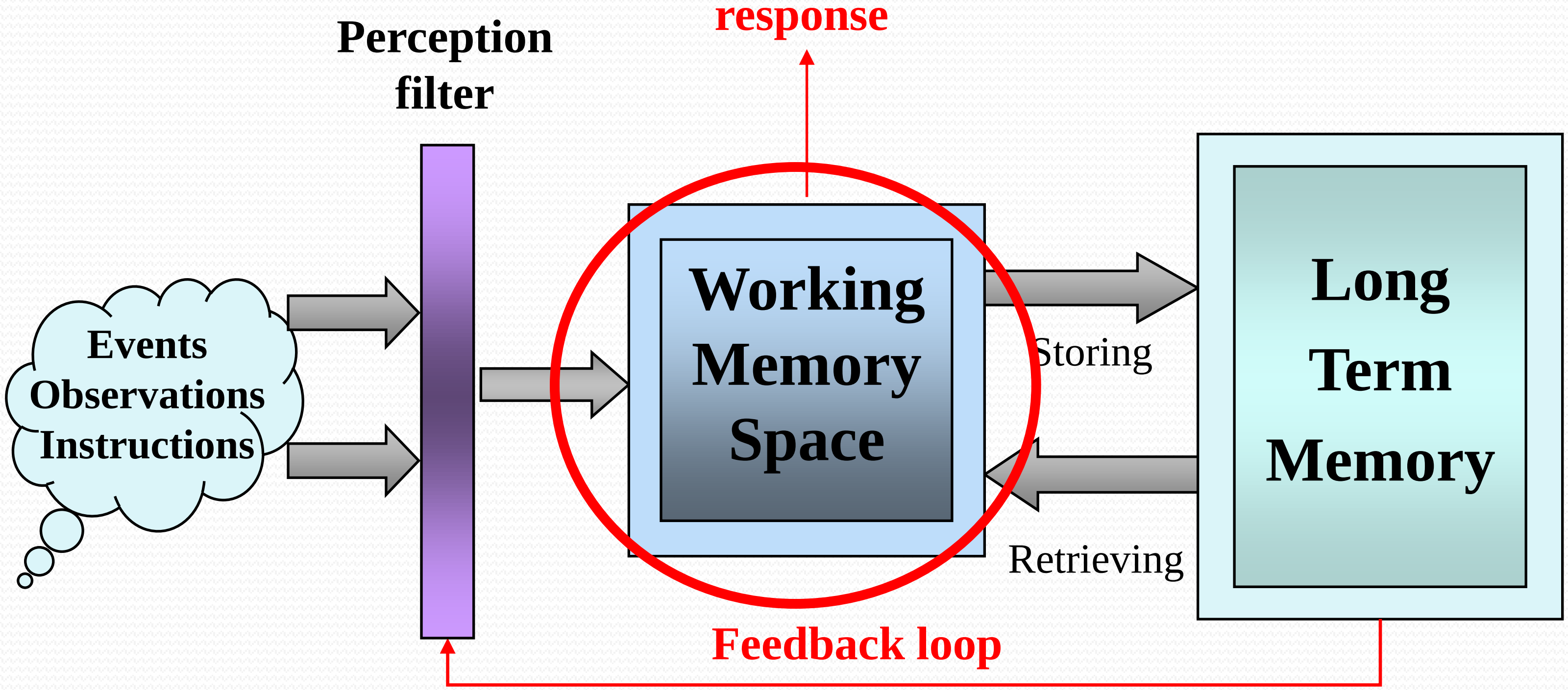
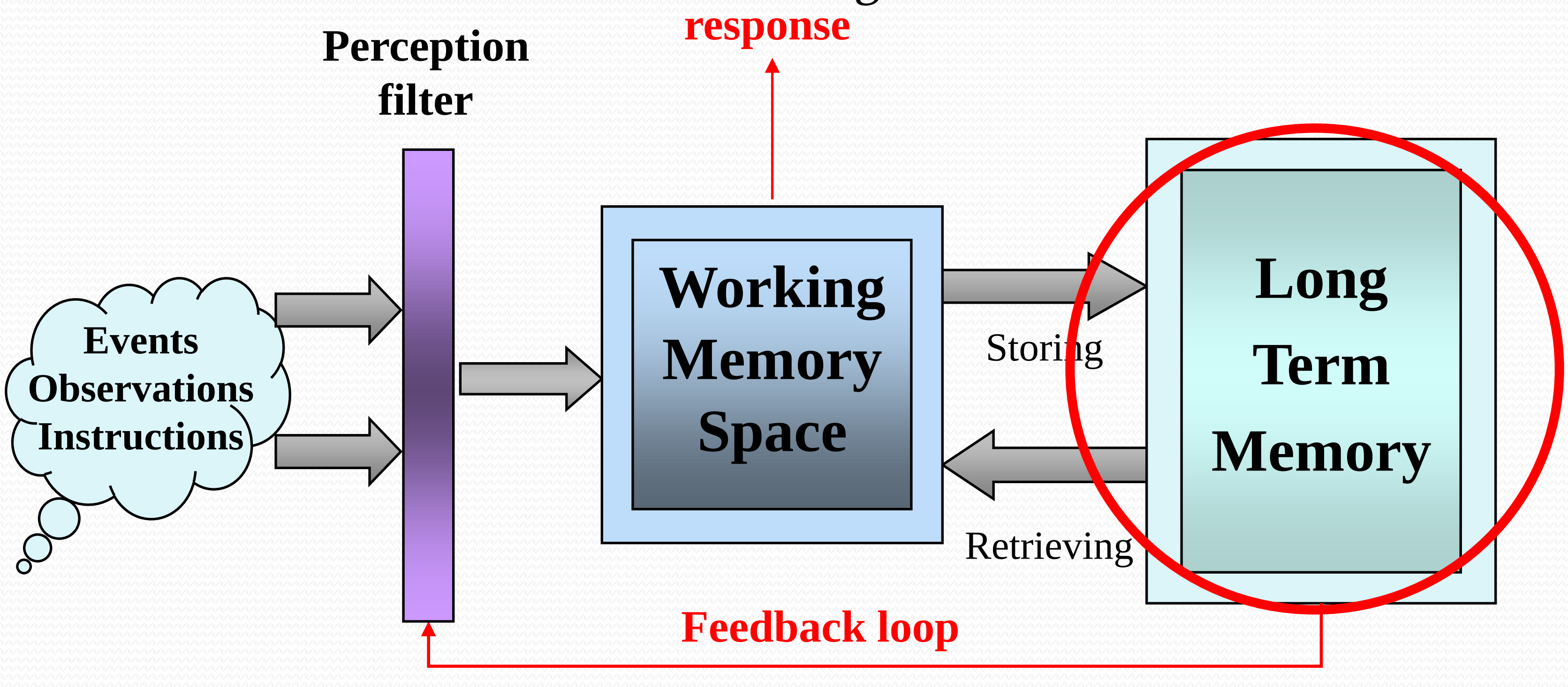


At the working memory stage, overloading of information due to instructions etc

Modified from Johnstone *et al* (1994)

An Information Processing Model

- A mechanism and framework for change



At the long term memory, it is useful to use pre labs and post labs to develop concepts and understanding

Modified from Johnstone *et al* (1994)

1st Year Chemistry Laboratory – Design

- 4 student groups timetabled
- Note ethical considerations
  - *Group 1 Control*
  - *Group 2 Pre-laboratory exercise used*
  - *Group 3 Mini-project used*
  - *Group 4 Pre-laboratory plus mini-project*
- How many questions did the students ask the demonstrators?
- How did their attitudes fare?

Johnstone *et al* (1994)

1st Year Chemistry Laboratory – Results

- Results

Group	Variable	Number of questions asked
Group 1	Control	121
Group 2	Pre-laboratory exercises used	58
Group 3	Mini-project used	145
Group 4	Pre-laboratory and mini-project	64

- Improvement in student attitudes towards laboratories
- Similar results found with pre lectures – preparing the mind for learning

Johnstone *et al* (1994)

Pre and Post Laboratory Exercise - Physics

- What does research tell us?
- Each student did 4 laboratories:
  - 2 with pre-laboratory exercise
  - 2 without pre-laboratory exercise
  - Students were assessed through demonstrator marked performance
    1. Post-laboratory exercises
    2. Student attitudes were also assessed
- What was found with pre-lab exercises?
  - Demonstrator marked exercise performance increased by ~ 5%
  - Post-lab exercise performance increased by ~11%
  - Students were much more positive about the pre laboratories (increase in attitudes).

Physics Education (1998) 33 (1) 22-29

Pre and Post Laboratories

- Preparing the mind for learning: pre-labs
  - Ensure that background information is recalled
  - Connect and revise previous knowledge
  - Practice appropriate data handling, drawings or calculations
  - Involve the student in planning
  - Establish confidence and competence
- Consolidating learning: post-labs
  - Interpretation of results
  - Report writing
  - Comparison with the class
  - Exploration of implications, applications and extensions
  - Discussion with demonstrator

Modified from Carnduff and Reid (2003)

The extraction of spinach pigments, separation by chromatography and estimation by spectrometry

- Pre-lab questions:
  - What is the hazard of inhaling methanol?
  - In what wavelength ranges do carotene, chlorophyll and xanthophyll each absorb strongly?
  - Draw a flow diagram for the experimental procedure
- Post-lab questions:
  - Decide which layer is in the separating funnel
  - What happens to the anhydrous sodium sulphate you used?

Université de Paris Sud, Orsay, cited in Carnduff and Reid (2003)

Some Key Factors Influencing Design

Stage	Activity	Tasks
Planning	Clear Aims	Make science real Expose ideas to empirical testing Develop skills
	Background	Know what happens at e.g. school and why Don't underestimate previous lab experiences
Before the laboratory	Pre-labs	Share aims for experiments Establish background information Plan experiments
During the laboratory	For the experimental	Keep manual brief Allow experimental freedom
After the laboratory	Post-labs	Apply ideas learned in a 'real world' setting For assessment, look at processes not 'right' answers

Modified from Reid and Shah (2007)

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