A Scientific Approach to the Teaching of Chemistry

Norman Reid
What do we know about how students learn chemistry and how can we make our teaching match this to maximise performance?

Norman Reid
Where are we Going?
Where are we Going?

- Why Chemistry is Difficult
- Information Processing - the Key?
- How Students Learn
- Bringing in Together
- The Attitude Problem
- A Total Picture
Where are we Going?

- Why Chemistry is Difficult
- Information Processing - the Key?
- How Students Learn
- Bringing in Together
- The Attitude Problem
- A Total Picture

What does research tell us about learning?
How can we apply it in practice?

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**Some History**

School Curriculum Revolution in Chemistry started in the 1960s

By the mid-1960s, reports emerged in Scotland:
- some of the chemistry is too difficult; parallels in other countries

**Research Studies:**
- Where are the difficulties?
- Is there anything we can do?
- What are the misconceptions?
- Are there underlying reasons for the problems?

Numerous Curriculum Revisions, especially the USA

**What was the actual evidence?**

**Could we be scientific about teaching and learning?**
### Some History

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Many Assertions
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Chemistry is abstract
Chemistry is full of concepts
Students hold many misconceptions
Many Assertions

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It is all the fault of secondary schools
It is all the fault of primary schools
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There is poor motivation and bad attitudes
They cannot do mathematics!
Many Assertions

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There is poor motivation and bad attitudes
They cannot do mathematics!

More roadshows, more glossy booklets, more advertising,
more school visits, more science centres ..... !!
Difficulties Survey (1970)

Most difficult topics
(from upper school as seen by first year students)
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Topics related to equations and the mole, eg. volumetric and gravimetric work, Avogadro and the mole.
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- Redox (eg E°) and ion electron ideas
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- Topics with some arithmetical content eg. thermochemistry and thermodynamics.
- Redox (eg $E^\circ$) and ion electron ideas
- Organic topics like esters, proteins, amines and carbonyls, aromaticity
Some Growing Ideas
Some Growing Ideas

Success might be linked to Information Load
Some Growing Ideas

Success might be linked to Information Load

Information Load: Started to be defined in terms of the number of ideas which a student has to hold at the same time in order to succeed.
Success might be linked to Information Load

Information Load: Started to be defined in terms of the number of ideas which a student has to hold at the same time in order to succeed.

Questions could be analysed by information load
Exploring Information Load
Exploring Information Load

I shall give you some dates
Exploring Information Load

I shall give you some dates

Turn the dates into numbers
Exploring Information Load

I shall give you some dates

Turn the dates into numbers

Put the numbers in ascending order
Trial Run
Trial Run

8 March 96
Trial Run

8 March 96

8 3 9 6
Trial Run

8 March 96

3 6 8 9

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Thursday, 15 October 2009
26 December
1 2 2 6
June 1984
8 May 1996
11 January 1901
23 December 1873
5.30 am 16 November 2007
5.30 am 16 November 2007

0 0 0 1 1 1 2 3 5 6 7
Working Memory
Working Memory

- Limited capacity: $7 \pm 2$
- Fixed genetically
- Grows with age
- Can be used efficiently or otherwise
Measuring Working Memory Capacity
Measuring Working Memory Capacity

Digit Span Backwards Test
Measuring Working Memory Capacity

Digit Span Backwards Test
Recall numbers backwards
Measuring Working Memory Capacity

Digit Span Backwards Test
Recall numbers backwards

Figural Intersection Test
Measuring Working Memory Capacity

Digit Span Backwards Test
Recall numbers backwards

Figural Intersection Test
Finding overlap between several geometrical shapes
Information Load and Success

Reasonable hypothesis:
As load increases, success will fall.

Expected Result

Success

Information Load Level of Questions
Information Load

Average Student Performance
%

Sudden collapse in performance

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Average Student Performance

Question Working Memory Demand

Working Memory > 7

Working Memory = 7

Working Memory < 7


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An Information Processing Model
(based on empirical evidence)
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- Events
- Observations
- Instructions

Perception Filter

Working Memory
- Interpreting
- Rearranging
- Comparing
- Problem Solving
- Preparing for storage

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An Information Processing Model
(based on empirical evidence)

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- Long Term Memory Storage
  - Long term store of infinite capacity.
    - (Knowledge, attitudes and skills)
  - Information can be stored in highly complex matrix, with cross links and connections
  - Sometimes stored as separate fragments
    - (e.g., rote memory learning)

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An Information Processing Model
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Events
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Instructions

Perception Filter

Working Memory
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Long Term Memory
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Feedback loop

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Thursday, 15 October 2009
Events, Observations, Instructions → Perception Filter → Working Memory → Interpreting, Rearranging, Comparing, Problem Solving, Preparing for storage → Feedback loop → Long Term Memory Storage

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Feedback loop

Predictions from the Model
Predictions from the Model

- If working memory is overloaded, learning will more or cease
- If the perception filter works efficiently, overload is less likely
- The filtration is controlled by what you know already
- If knowledge is stored in linked fashion, it will be more easily recalled
Predictions from the Model

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Learning

Everyone learns in essentially the same way
There are many variations in the details

Events, Observations, Instructions → Perception, Filter → Working Memory → Interpreting, Rearranging, Comparing, Problem Solving, Preparing for storage → Long Term Memory, Storage

Long term store of infinite capacity. (Knowledge, attitudes and skills)
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Feedback loop
Long Term Memory

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Feedback loop

Interpreting
Rearranging
Comparing
Problem Solving
Preparing for storage

Working Memory

Perception Filter

Events
Observations
Instructions

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Selection linked to ability to see what is important (field dependency)
Long Term Memory

Storage

- Long term store of infinite capacity.
  (Knowledge, attitudes and skills)
- Information can be stored in highly complex matrix, with cross links and connections
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Feedback loop
The working memory is of limited capacity (7±2)
Its capacity cannot be increased
It can be used more efficiently

Long Term Memory
Storage
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Feedback loop

Working Memory
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Perception Filter

Events
Observations
Instructions

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Long Term Memory

Storage
Long term store of infinite capacity. (Knowledge, attitudes and skills)
Information can be stored in highly complex matrix, with cross links and connections
Sometimes stored as separate fragments (eg rote memory learning)
Selection based on previous knowledge, experience and attitudes
Long Term Memory

Storage

Long term store of infinite capacity. (Knowledge, attitudes and skills)
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Feedback loop

Working Memory

Interpreting
Rearranging
Comparing
Problem Solving
Preparing for storage

Perception Filter

Events
Observations
Instructions

Thursday, 15 October 2009
Students vary in the way they store information

- **Extent of meaningful links between ideas**
- **Favoured storage: visually or symbolically**
- **Conceptual understanding related to links between ideas**

*Long Term Memory (Storage)*
- Long term store of infinite capacity.
- (Knowledge, attitudes and skills)
- Information can be stored in highly complex matrix, with cross links and connections
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**Perception Filter**
- Events
- Observations
- Instructions

**Working Memory**
- Interpreting
- Rearranging
- Comparing
- Problem Solving
- Preparing for storage

**Feedback loop**

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The Idea of Pre-learning
The Idea of Pre-learning

Watch the skilled school teacher
The Idea of Pre-learning

Watch the skilled school teacher

The idea of the Pre-lecture
The Idea of Pre-learning

Watch the skilled school teacher

The idea of the Pre-lecture

The idea of the Pre-laboratory
# First Year General Chemistry Class

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<th>Pre-learning</th>
<th>Upper Group Average</th>
<th>Lower Group Average</th>
<th>Difference</th>
<th>Significance</th>
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**Craig Gray and Ghassan Sirhan**

*University Chemistry Education, 1999, 5, 52-58.*
# Preparing the Mind for Learning

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Four Experiments

Each student did two of them with pre-laboratory exercises and two without. Combinations were varied.

Each student was assessed on learning by two means:

- Traditional demonstrator marked performance
- Post-laboratory exercises, testing understanding and application of ideas.

Student attitudes were assessed.
Physics Laboratories

What was Found

Pre-laboratories increased performance on student marking by around 5%
Pre-laboratories increased performance on exercises by around 11%
Students were dramatically more positive about pre-laboratories

First Year Chemistry Laboratories

What was done

Four Groups of Students (N = 500)

<table>
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<th>Control</th>
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<td>Group 2</td>
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<td>Group 4</td>
<td>Pre-laboratory plus miniproject</td>
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Understanding checked by looking at questions asked
Attitudes measured
What was found
First Year Chemistry Laboratories

What was found

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## First Year Chemistry Laboratories

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*Enhancing Chemistry Laboratories, RSC*
Reducing the Load on Working Memory
Reducing the Load on Working Memory

This must NOT involve:

Changing what is to be taught
Changing the time demand
Simply avoiding problem areas
Massive re-training of lecturers/teachers
Reducing the Load on Working Memory
Reducing the Load on Working Memory

It may involve:

- Changing the teaching order
- Modifying speed and sequencing
- Breaking down complex areas
- Allowing learning to fit human psychology
Can We Reduce the Load on Working Memory?

The work of Eleni Danili in Greece
Can We Reduce the Load on Working Memory?

The work of Eleni Danili in Greece

She measured the working memory capacity of the students and also their ability to 'see the message from the noise'.
Can We Reduce the Load on Working Memory?

The work of Eleni Danili in Greece

She measured the working memory capacity of the students and also their ability to ‘see the message from the noise’.

She re-designed a large section of chemistry teaching at school level, specifically to reduce working memory overload problems.
Performance Depends on ....

- Working Memory Capacity
- Field dependency (seeing the ‘message’ amidst the ‘noise’)
Performance Depends on ....

- **Working Memory Capacity**

- **Field dependency** (seeing the ‘message’ amidst the ‘noise’)

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**Thursday, 15 October 2009**
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Thursday, 15 October 2009
Performance Depends on ....

- **Working Memory Capacity**

- **Field dependency** (seeing the ‘message’ amidst the ‘noise’)

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Thursday, 15 October 2009
Performance Improvement

Using Control and Experimental Groups
(pre and post tests)

Centre for Science Education, University of Glasgow, Scotland
Performance Improvement

Using Control and Experimental Groups (pre and post tests)

Normal Teaching
Performance Improvement

Using Control and Experimental Groups
(pre and post tests)

Normal Teaching

Reduce working memory demand
Performance Improvement

Using Control and Experimental Groups
(pre and post tests)

Normal Teaching

Reduce working memory demand

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Thursday, 15 October 2009
Performance Improvement

Using Control and Experimental Groups (pre and post tests)

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N = 211

Normal Teaching

Reduce working memory demand

Centre for Science Education, University of Glasgow, Scotland

Thursday, 15 October 2009
Performance Improvement

Using Control and Experimental Groups
(pre and post tests)

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A Larger Experiment
(800 Senior School Students)

Furat Hussein in the Emirates

Centre for Science Education, University of Glasgow, Scotland
A Larger Experiment
(800 Senior School Students)

Testing Two Hypotheses

1. Reducing load on working memory will bring improved understanding.
2. Use appropriate applications and interaction will enhance attitudes

Furat Hussein in the Emirates

Centre for Science Education, University of Glasgow, Scotland

Thursday, 15 October 2009
A Larger Experiment
(800 Senior School Students)

Testing Two Hypotheses

1. Reducing load on working memory will bring improved understanding.
2. Use appropriate applications and interaction will enhance attitudes

- Minimise working memory overload;
- Use relevant applications;
- Encourage understanding not memorising;
- Link new material to previously taught material in a meaningful way

Furat Hussein in the Emirates
Experimental Structure
Group 1
(200 students)

Periodic Table
(Booklet)

Chemical Equations
(normal teaching)

Assessment

Group 2
(200 students)

Periodic Table
(normal teaching)

Chemical Equations
(Booklet)

Assessment
Experimental Structure

Group 1
(200 students)

Periodic Table
(Booklet)

Chemical Equations
(normal teaching)

Assessment

Group 2
(200 students)

Periodic Table
(normal teaching)

Chemical Equations
(Booklet)

Assessment

Group 1
(200 students)

Organic Chemistry
(Booklet)

Acids and Alkalis
(normal teaching)

Assessment

Group 2
(200 students)

Organic Chemistry
(normal teaching)

Acids and Alkalis
(Booklet)

Assessment

Centre for Science Education, University of Glasgow, Scotland
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Centre for Science Education, University of Glasgow, Scotland
## Performance Data

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Centre for Science Education, University of Glasgow, Scotland

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## Some Attitude Changes

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<tr>
<td><strong>I like chemistry lessons</strong></td>
<td>N = 115</td>
<td>N = 400</td>
</tr>
<tr>
<td><strong>I hate chemistry lessons</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Boring</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Interesting</strong></td>
<td></td>
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<tr>
<td><strong>Easy</strong></td>
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<tr>
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<tr>
<td><strong>Useful</strong></td>
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<td></td>
</tr>
<tr>
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<tr>
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<td></td>
</tr>
<tr>
<td><strong>Boring</strong></td>
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\[
\chi^2
\]

\[
\begin{array}{cccccccc}
   \text{I like chemistry lessons} & 40 & 17 & 11 & 10 & 12 & 10 \\
   \text{I hate chemistry lessons} & 70 & 10 & 3  & 2  & 3  & 12 \\
   \text{Boring}                     & 17 & 9  & 11 & 14 & 20 & 29 \\
   \text{Interesting}                & 20 & 1  & 1  & 2  & 5  & 71 \\
   \text{Easy}                       & 19 & 21 & 16 & 7  & 11 & 26 \\
   \text{Difficult}                  & 60 & 9  & 1  & 4  & 1  & 25 \\
   \text{Useless}                    & 8  & 4  & 5  & 8  & 13 & 62 \\
   \text{Useful}                     & 10 & 8  & 2  & 2  & 5  & 73 \\
   \text{Important}                  & 60 & 10 & 10 & 4  & 8  & 8  \\
   \text{Unimportant}                & 69 & 11 & 2  & 3  & 6  & 9  \\
   \text{Enjoyable}                  & 18 & 17 & 18 & 16 & 8  & 2  \\
   \text{Boring}                     & 66 & 12 & 1  & 1  & 3  & 17 \\
\end{array}
\]

\[
36.7 \ (p < 0.001) \quad 66.0 \ (p < 0.001) \quad 47.1 \ (p < 0.001) \quad 14.1 \ (p < 0.001) \quad 13.2 \ (p < 0.001) \quad 104.1 \ (p < 0.001)
\]
### Some Attitude Changes

<table>
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<tr>
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<tr>
<td>I hate chemistry lessons</td>
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<td>10</td>
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<tr>
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<td>17</td>
<td>20</td>
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<tr>
<td>Interesting</td>
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Control Group: N = 115
Experimental Group: N = 400

Centre for Science Education, University of Glasgow, Scotland
I am enjoying the subject | I am NOT enjoying the subject
---|---
15 | 24 | 13 | 25 | 9 | 14 | 66 | 6 | 2 | 5 | 9 | 19

I feel I am NOT coping well | I feel I am coping well
---|---
18 | 10 | 11 | 10 | 24 | 27 | 30 | 10 | 11 | 3 | 7 | 39

I find it very easy | find it very hard
---|---
22 | 27 | 23 | 16 | 8 | 4 | 67 | 4 | 3 | 2 | 2 | 22

I am NOT obtaining a lot of new skills | I am obtaining a lot of new skills
---|---
6 | 12 | 12 | 12 | 24 | 34 | 5 | 9 | 10 | 9 | 12 | 55

I am getting better in the subject | I am getting worse in the subject
---|---
35 | 23 | 15 | 12 | 9 | 6 | 68 | 6 | 2 | 1 | 7 | 16

It is definitely 'my' subject | It is definitely not 'my' subject
---|---
15 | 23 | 29 | 18 | 10 | 5 | 35 | 9 | 14 | 20 | 20 | 2

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χ²

104.2 (p < 0.001) 39.6 (p < 0.001) 129.0 (p < 0.001) 19.6 (p < 0.001) 67.5 (p < 0.001) 31.1 (p < 0.01)
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<th></th>
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<th>$p &lt; 0.001$</th>
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<td><strong>I am enjoying the subject</strong></td>
<td>104.2</td>
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<td>104.2</td>
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</tr>
<tr>
<td><strong>I feel I am NOT coping well</strong></td>
<td>39.6</td>
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</tr>
<tr>
<td><strong>I feel I am coping well</strong></td>
<td>39.6</td>
<td></td>
</tr>
<tr>
<td><strong>I find it very easy</strong></td>
<td>129.0</td>
<td></td>
</tr>
<tr>
<td><strong>find it very hard</strong></td>
<td>129.0</td>
<td></td>
</tr>
<tr>
<td><strong>I am NOT obtaining a lot of new skills</strong></td>
<td>19.6</td>
<td></td>
</tr>
<tr>
<td><strong>I am obtaining a lot of new skills</strong></td>
<td>19.6</td>
<td></td>
</tr>
<tr>
<td><strong>I am getting better in the subject</strong></td>
<td>67.5</td>
<td></td>
</tr>
<tr>
<td><strong>I am getting worse in the subject</strong></td>
<td>67.5</td>
<td></td>
</tr>
<tr>
<td><strong>It is definitely 'my' subject</strong></td>
<td>31.1</td>
<td></td>
</tr>
<tr>
<td><strong>It is definitely not 'my' subject</strong></td>
<td>31.1</td>
<td></td>
</tr>
</tbody>
</table>

**Control Group**

| $N = 115$ |

**Experimental Group**

| $N = 400$ |
Long Term Memory

Storage

Long term store of infinite capacity.
(Knowledge, attitudes and skills)
Information can be stored in highly complex matrix, with cross links and connections
Sometimes stored as separate fragments (eg rote memory learning)
Improve Selection

Lower Working Memory demand

Encourage Understanding
Improve Selection

Lower Working Memory demand

Encourage Understanding
Improve Selection

Lower Working Memory demand

Encourage Understanding
**Improve Selection**

**Lower Working Memory demand**

**Encourage Understanding**

---

**Long Term Memory**

- **Storage**
  - Long term store of infinite capacity.
  - (Knowledge, attitudes and skills)
  - Information can be stored in highly complex matrix, with cross links and connections
  - Sometimes stored as separate fragments (e.g., rote memory learning)

---

**Pre-learning**

**Re-design presentation**

**Emphasise links and assess for understanding**
Teaching and Learning Successfully in Physical Sciences

Stimulating and Enjoyable?
Teaching and Learning Successfully in Physical Sciences

Stimulating and Enjoyable?

What does Research Evidence tell us about attitudes?
Some Key Research Findings
Some Key Research Findings

- Interest develops early (by age 14)
Some Key Research Findings

- Interest develops early (by age 14)
- Boys and girls are equally interested
Some Key Research Findings

- Interest develops early (by age 14)
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Some Key Research Findings

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How to Attract Learners to Physical Sciences

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- Interest develops early (by age 14)
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- School teachers have a very critical role
- Things outside the school have almost no impact
- There is a successful curriculum approach
- Integrated science courses are disasters
- Career potential must be perceived
A Successful Curriculum Approach
A Successful Curriculum Approach

The Applications-Led Idea
A Successful Curriculum Approach

The Applications-Led Idea

My first encounter:

The findings of Elena Skryabina in relation to Physics
What She Found
(greatly over-simplified)
What She Found
(greatly over-simplified)

Attitudes
Towards
Physics

Age

10  12  14  16  18

Centre for Science Education, University of Glasgow, Scotland
What She Found
(greatly over-simplified)

Attitudes Towards Physics

Usual pattern
What She Found
(greatly over-simplified)

Attitudes Towards Physics

What was found

Usual pattern

Age

10 12 14 16 18
What She Found
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Attitudes
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What was found

Age

Centre for Science Education, University of Glasgow, Scotland
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Attitudes Towards Physics

Glamour, from ignorance!

Age

What was found

Centre for Science Education, University of Glasgow, Scotland

Thursday, 15 October 2009
What She Found
(greatly over-simplified)

<table>
<thead>
<tr>
<th>Age</th>
<th>Integrated science</th>
<th>Glamour, from ignorance!</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
</tr>
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<td></td>
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(greatly over-simplified)

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<td>---</td>
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<tr>
<td>Glamour, from ignorance!</td>
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</tbody>
</table>

Thursday, 15 October 2009
What She Found
(greatly over-simplified)

Attitudes Towards Physics

- Glamour, from ignorance!
- Applications-led Curriculum
- Integrated science
- Too demanding

What was found

Age
10 12 14 16 18

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Thursday, 15 October 2009
The Applications-led Syllabus
(Scotland aged 14-16)

1990
Unit 1: Telecommunication
Unit 2: Using Electricity
Unit 3: Health Physics
Unit 4: Electronics
Unit 5: Transport
Unit 6: Energy Matters
Unit 7: Leisure
Unit 8: Space Physics
### The Applications-led Syllabus (Scotland aged 14-16)

<table>
<thead>
<tr>
<th>1990</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1: Telecommunication</td>
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</tr>
<tr>
<td>Unit 2: Using Electricity</td>
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</tr>
<tr>
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</tr>
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The physics or chemistry to be taught and its teaching order is determined by the learners - their needs, what is perceived by them to be related to their context and lifestyle.
Possible Definition

The physics or chemistry to be taught and its teaching order is determined by the learners - their needs, what is perceived by them to be related to their context and lifestyle.
More on Attitudes
More on Attitudes

Positive Attitudes arise when:

⭐️ The curriculum is designed as applications-led
⭐️ It is taught by enthusiastic and supportive subject specialists
Positive Attitudes arise when:

- The curriculum is designed as applications-led
- It is taught by enthusiastic and supportive subject specialists

What about the Working Memory Problem??
Attitudes and Working Memory Capacity
<table>
<thead>
<tr>
<th></th>
<th>Kendall’s Tau-b Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sample = 714, Aged 12-15</strong></td>
<td></td>
</tr>
<tr>
<td>South Korea</td>
<td></td>
</tr>
<tr>
<td>I am enjoying studying science</td>
<td>0.17</td>
</tr>
<tr>
<td>Science is interesting</td>
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### Attitudes and Working Memory Capacity

**Sample** = 714, Aged 12-15  
**South Korea**

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**The work of Eun Sook Jung in South Korea**

*Working Memory and Attitudes (2009) Research in Science and Technological Education*
## Attitudes and Working Memory Capacity

<table>
<thead>
<tr>
<th>Are you interested in science?</th>
<th>Level 1</th>
<th></th>
<th>Level 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High (N = 100)</td>
<td>Mid (N = 166)</td>
<td>Low (N = 98)</td>
<td>High (N = 95)</td>
</tr>
<tr>
<td>YES</td>
<td>66%</td>
<td>55%</td>
<td>39%</td>
<td>48%</td>
</tr>
<tr>
<td>NO</td>
<td>33%</td>
<td>42%</td>
<td>57%</td>
<td>53%</td>
</tr>
</tbody>
</table>

### Notes

- The table above shows the distribution of attitudes towards science among different working memory capacity levels for both levels 1 and 3.
- The percentages indicate the proportion of participants who responded 'YES' or 'NO' to the question of interest in science.
- The table includes data on high, mid, and low working memory capacity groups, with sample sizes (N) provided for each category.

**Centre for Science Education, University of Glasgow, Scotland**

**Thursday, 15 October 2009**
## Attitudes and Working Memory Capacity

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*Thursday, 15 October 2009*
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**Thursday, 15 October 2009**

*Centre for Science Education, University of Glasgow, Scotland*
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<tbody>
<tr>
<td></td>
<td>High (N = 100)</td>
<td>Mid (N = 166)</td>
<td>Low (N = 98)</td>
<td>High (N = 95)</td>
</tr>
<tr>
<td>I have tried to understand science</td>
<td>71%</td>
<td>54%</td>
<td>50%</td>
<td>70%</td>
</tr>
<tr>
<td>I have tried to memorise science</td>
<td>24%</td>
<td>34%</td>
<td>39%</td>
<td>21%</td>
</tr>
</tbody>
</table>

**I have tried to understand science knowledge such as concepts, rules, theory as much as I can**
## Attitudes and Working Memory Capacity

<table>
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<tr>
<td></td>
<td>Mid (N = 166)</td>
<td>Mid (N = 172)</td>
</tr>
<tr>
<td></td>
<td>Low (N = 98)</td>
<td>Low (N = 83)</td>
</tr>
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<td>61%</td>
</tr>
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<td></td>
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<td>35%</td>
</tr>
<tr>
<td></td>
<td>39%</td>
<td>45%</td>
</tr>
</tbody>
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I have tried to understand science knowledge such as concepts, rules, theory as much as I can.
### Attitudes and Working Memory Capacity

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I have tried to understand science knowledge such as concepts, rules, theory as much as I can.
Attitudes and Working Memory Capacity

A Working Hypothesis
A Working Hypothesis

Learners seek to understand

High Working Memory Capacity

Low Working Memory Capacity
A Working Hypothesis

Learners seek to understand

High Working Memory Capacity

Understanding mainly possible

Low Working Memory Capacity

Understanding often impossible
A Working Hypothesis

High Working Memory Capacity

Learners seek to understand

Low Working Memory Capacity

Understanding mainly possible

More positive attitudes

Understanding often impossible

Less positive attitudes
<table>
<thead>
<tr>
<th>Accessible</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>Stimulating</td>
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Making Learning Accessible, Stimulating and Enjoyable

What Does Research Tell Us??

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</tr>
</tbody>
</table>
Tries to understand the physical world around
Tries to understand the physical world around

Working Memory can cope
Tries to understand the physical world around

Working Memory can cope

Working Memory is overloaded
I find it difficult
I cannot understand
I shall never understand
I shall give up and opt out
I find it difficult
I cannot understand
I shall never understand
I shall give up and opt out

Working Memory is overloaded
Memorisation is the only way to pass
I find it difficult
I cannot understand
I shall never understand
I shall give up and opt out

Working Memory is overloaded
Memorisation is the only way to pass

I can cope
I can understand
I find it accessible, stimulating and enjoyable
I find it difficult
I cannot understand
I shall never understand
I shall give up and opt out

Working Memory
is overloaded
Memorisation is the
only way to pass

Working Memory
is coping
Understanding
is possible

I can cope
I can understand
I find it accessible,
stimulating and enjoyable
A Scientific Approach to the Teaching of Chemistry

Norman Reid
dr_n@btinternet.com
A Scientific Approach to the Teaching of Chemistry

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dr_n@btinternet.com

Thank You