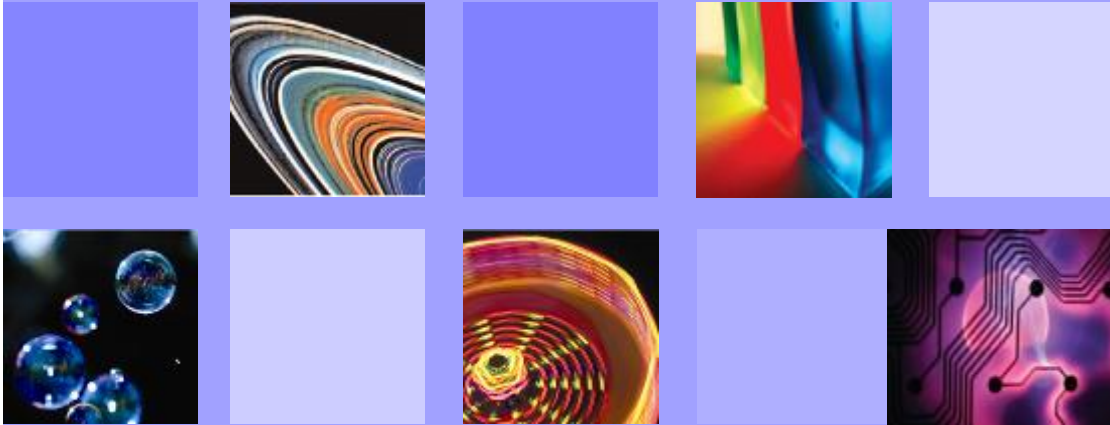


# The Mole Misunderstood



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# Overview

- Why do people find science difficult?
- The mole as a '*Threshold concept & Troublesome Knowledge*'
- And people say...different perspectives on the mole
- Hot Pen writing
- What can be done?

# Why is science difficult?

1. Chemical concepts - presented in school classroom as the solutions to problems in which the learners have little interest in or have never experienced
2. Constant shifts between talking about actual substances that can be seen touched and explanations via abstract models.
3. Working memory space in our brains has limited capacity
4. Language also contributes to information overload
  - Specialist language explained
  - Tacit language not explained
  - Words + a multitude of signs and symbols, graphs, charts, diagrams, equations and chemical formulae
5. Mathematical ability – a poor background leads to panic
6. Unlearning misconceptions is difficult

## Research on issues with learning science....

*"When students cannot 'see' particles they cannot really understand chemical reactions and so the fabric of chemistry is lost to them in a haze of impenetrable events completely at odds with their every day experiences of a "continuous" world."*

(Kind, 2005)

*Chemistry is a conceptual subject and, in order to explain many of these concepts, models are used to describe and explain the microscopic world and relate it to the macroscopic properties of matter. As students progress in chemistry the models they use change and many contradict their everyday experiences and use of language. (Taber, 2002, 2009)*

*Area is complicated by misconceptions – 'Atoms and molecules have macroscopic properties: they expand and lose weight when heated, have uniform densities and well-defined colours, are malleable, change shape under pressure,.. (Talanquer JCE 2006)*

## And the consequences....

Chemistry – the practical subject ?

In 2009, only 55.7% of students that achieve an A\* in Chemistry at GCSE and 35.9% of students that achieve an A grade went on take Chemistry as an A-level subject

# The mole a *Threshold Concept*...

*'Moles as a concept is too alien for most to cope with and so many students give up trying to understand the real concepts... and end up rote learning the equations and applying them...this means that they can't cope with anything out of the standard question'*

A *Threshold Concept* is a 'core concept', a conceptual 'building block' that leads to progression in understanding of the subject. They are:

- *Transformative*- 'seismic', once 'got' its effect creates a significant shift in the student view of a subject
- *Irreversible*- this new view is unlikely to be unlearned
- *Integrative* - understanding it exposes links with other areas
- Potentially *troublesome knowledge* – students handle material in *ritualistic and mechanical manner* .

# What did we investigate and how?

1. Why do students at different stages of their education struggle with the mole?
2. Want to explore ways in which we can support students in understanding and applying the concept correctly

## How?

3 survey questionnaires aimed at school students university students and teachers

Questionnaires were semi-structured and included a range of open and closed questions as well as 'Hot pen writing.'

The results from the survey were both quantitative and qualitative.

Quantitative data was analysed using statistical tests and qualitative data required coding. All the responses were then organised into a smaller number of categories & then used to form frequency tables.

# Survey Tool: questions included

- Which science related subjects they found most difficult?
- Preferred learning styles & most beneficial activities during chemistry lessons?
- Is it important to link science concepts to real-life?
- Use of practical activities?
- Most difficult topics in chemistry?
- Knowledge of the mole concept and rating of its importance?
- Did find mole difficult?
- What would help?

# Participants

270 questionnaires given out, 111 returned (41% response rate)

- 61 university students (45 on chemistry degrees, across years)
- 44 secondary students (year 10 & 11 plus some year 12 at 2 schools, random sample , mixed ability)
- 6 teachers/lecturers (1-15 years experience)

## Issues with the mole:

*"Have you ever struggled to understand the concept of 'the Mole'?"* 68% of GCSE and A-level students and 55% of the university students (who had studied the mole) stated they had struggled with this concept at one time or other.

### Why?

- For GCSE and AS level students – *"poor resources in lessons", "confusing text books", "poor teaching", "the concept itself is confusing", "complicated", "new", "difficult to understand", "not enough lesson time is spent on the topic", "it involves maths"*.
- University students- 30% cited *"poor teaching"* and 22% said *"it was a difficult concept to understand"*. Plus *"poor maths ability", "confusion", "difficulties in remembering and manipulating the equations", "no direct definition of the mole provided" and "difficult to relate to real life"*.

## When is mole introduced? At GCSE?

- OCR 21<sup>st</sup> Century science – only in triple science module C7
- OCR Gateway specification encourages to learn about the mole in module C5 called 'How much?'
- Edexcel specification requires students that are taking triple award sciences to have an even more extensive knowledge about the mole
- AQA specification requires higher students to have a basic understanding of the mole but they are not required to carry out any calculations

University students 44% had first done the mole at GCSE, 48% had first studied the mole during A-levels

34% of 15-18 year olds surveyed have taken or are taking triple science. 78% of these students have studied the mole at GCSE

# Hot Pen writing

How do we assess conceptual understanding?

To avoid the 'Maths Problem', possibilities include:

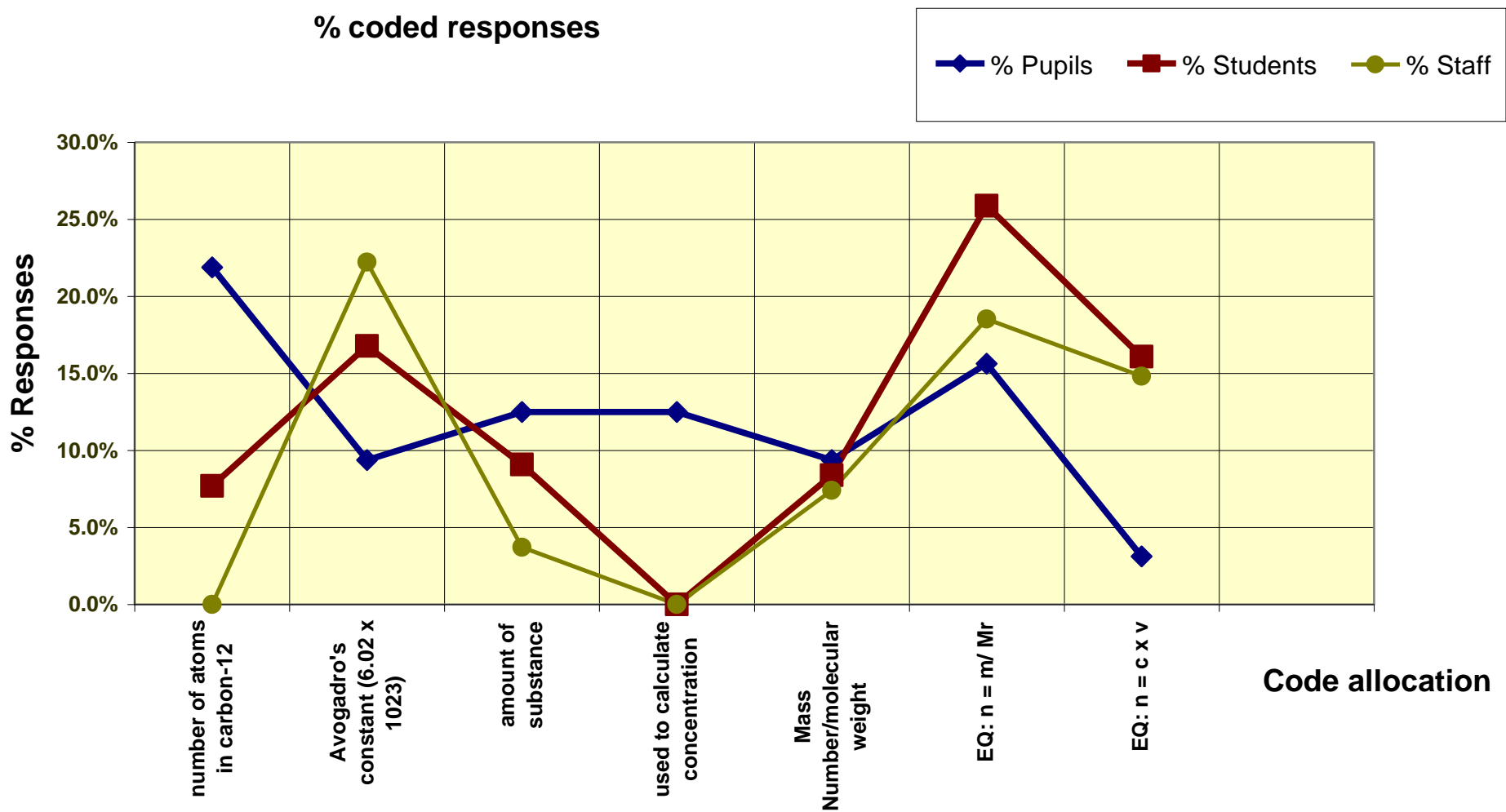
- Using a concept inventory (usually MCQ based)
- Drawing diagrams and pictures
- Making models
- Concept maps/ cartoons

We chose **Hot pen writing** – Invite respondents to write down or draw as much as they can about a certain topic (the mole) in a certain time-period (e.g. 5 minutes)

The responses indicate what people do/don't know about the topic.

Responses can be coded

## % coded responses



# Results

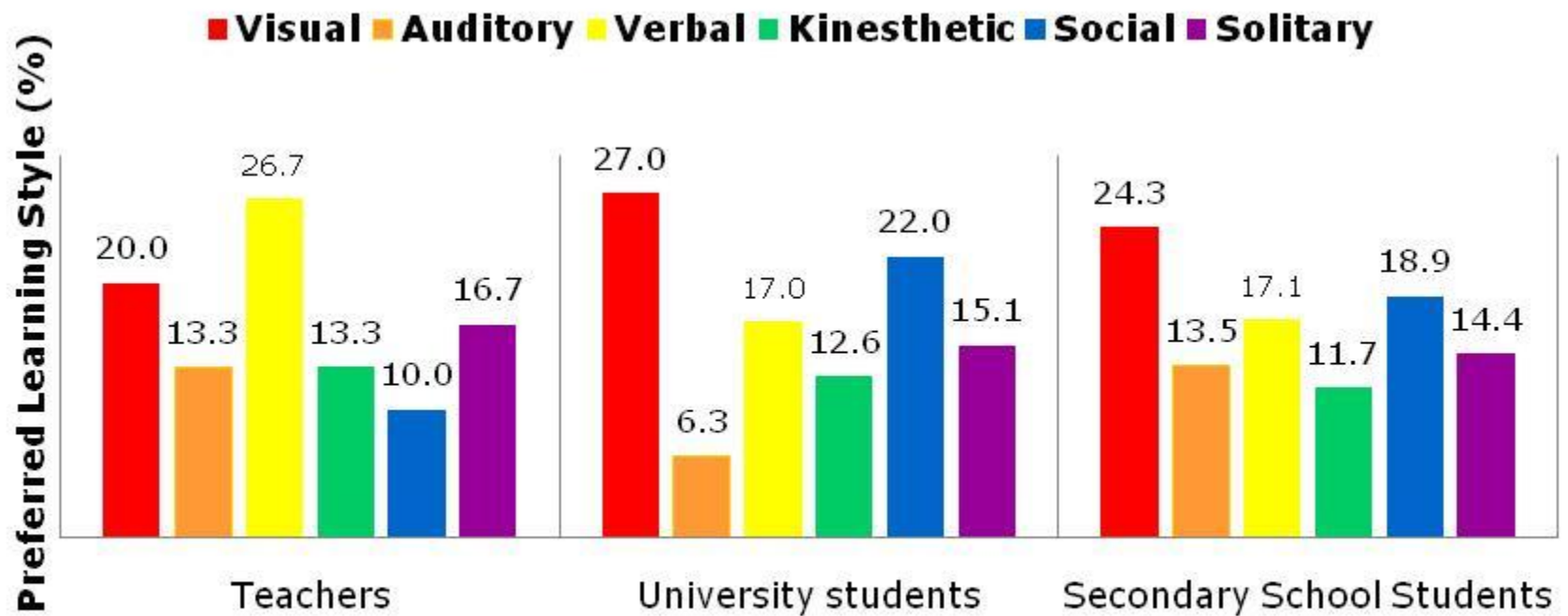
## University students

<b><u>Mole knowledge</u></b>	<b><u>Frequency</u></b>	
relationship to Avogadro's constant	19	
Avogadro's constant ( $6.02 \times 10^{23}$ )	24	
relationship to molecular weight	9	
weight of an element/ compound	3	
amount of substance	13	
large number	1	
number of atoms in 12 g of carbon	11	
symbol (n)		
unit (mol)	2	
<b>EQUATIONS :</b>		
n = m/ Mr	37	3 written explanations
		4 in triangle forms
		20 in equation forms
n = c x v	23	5 written explanations
		5 in triangle forms
		13 in equation forms
gas equation	1	

# What could be done?

- Expose all students to the mole early in GCSE
- Teach concept at a basic level using words and analogies
- Develop concept stepwise & review it
- Show the importance of the mole + its relationship to real-life
- Provide extra support for students who struggle with maths
- Use a variety of learning styles and resources to make learning interactive and fun
- Use a range of assessment tools to do frequent checks on understanding
- Teachers shouldn't assume prior knowledge and full understanding of the concept.

# Learning Style – a mismatch?



# Recommended mole resources

## 1. Moles calculator

**CELS**  
Concentration calculator

**Solute**

Mass / g  
1.012

Moles  
 $8.0317 \times 10^{-3}$

RMM  
126

**Solvent**

Volume / cm<sup>3</sup>  
260

**Solution**

Conc / M  
 $3.0891 \times 10^{-2}$

Instructions

cepts

[qa/ch](#)

nd  
help

bring

- only covers some of the concepts involved with the mole.

## The next step....

- Could this approach work?
- Explore other misconceptions using Hot pen writing
- Need more analysis of teacher perspective

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