

Teaching outside the discipline: case studies of trainee teachers' understanding of chemical reactions.

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# Context: trainee teachers in England

- Majority follow a Postgraduate Certificate in Education (PGCE) course
- Come with a range of degree subjects across the sciences
- Different experiences and qualifications in chemistry, at least to age 16
- Trainees frequently expected to teach all sciences up to age 14 and often a second or even third science to age 16

# Research question:

- *How does using dynamic computer modelling assess and provide insights into non-specialist subject knowledge of chemical processes?*

# Background to the study

- Learners' misconceptions (*alternative frameworks, intuition, cognitive structures, children's science*)
- Modelling in chemistry
- Computer models in chemistry

# Learners' misconceptions in chemistry

- Reactions and bonding
- Bond angles
- Free atoms
- Combustion
- Neutralisation
- Precipitation

BUT.... Ages groups up to 18 years – little about trainee teachers

# Modelling

- Diagrams
- Graphs
- Symbols
- Solid models
- Visualise the sub-microscopic to explain the macroscopic

# Computer models in chemistry

- Many have been developed ....
- ....but frequently do not allow trainees to construct models themselves
- *ChemSense* provides a simple tool box involving atoms, ions, bond, 3-D representations
- Frame-by-frame animations support reasoning and discussion

# Methods

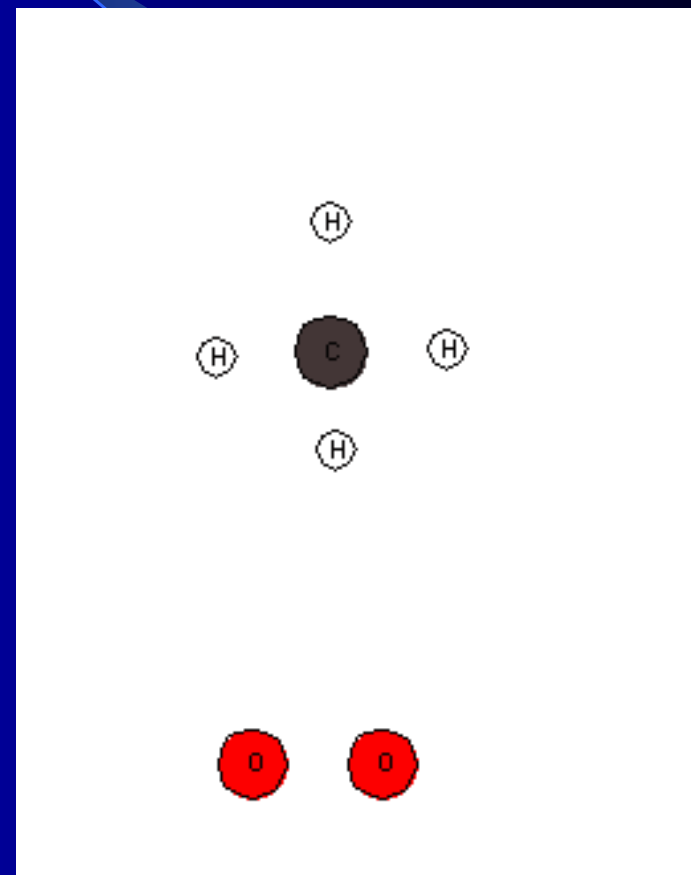
- Sample of 6 volunteers (5 biology, 1 physics)
- Analysis of animations frame-by-frame and as a whole
- Interviews to validate researcher's own analysis, to answer any questions and to provide rich data about the trainees' own perspectives

# The four reactions

- Combustion: methane
- Neutralisation: hydrochloric acid/sodium hydroxide
- Thermal decomposition: copper carbonate
- Precipitation: lead iodide
- All common reactions met at ages 14 - 16

# Findings/discussion: free atoms

- Depiction of molecules
- Bond breaking
- Movement of free atoms (several frames)
- Bond formation
- Why these ideas about free atoms?



# Findings/discussion: bond angles

- General lack of knowledge about bond angles
- Examples: carbon dioxide and water with angles from 45 to 115 degrees
- Compares with study of 15-18 year olds where water shown incorrectly in 76/128
- Why? Electron repulsion not studied but ball and stick frequently met in textbooks

# Findings/discussion: the covalent bond

- Confusion between single and double bonds
- Lines and overlapping spheres used together
- Cross bonding
- Hydrochloric acid shown as covalent
- Why? Multiple models (Taber, 2000) compounded by overlapping shells with shared electrons?

# Findings/discussion: the ionic bond

- Sodium chloride: ions and covalent - same animation
- Potassium iodide as covalent and paired ions
- Showing ionic bonds as lines
- Why? alternative or molecular framework rather than an electrostatic model (Taber, 2000)
- Both frameworks – in transition?

# The models used

- 2-D - although 3-D representations possible
- Episodes. Thinking follows reaction equation:

reactants  $\rightarrow$  intermediates  $\rightarrow$  products

- Showed balanced equations

# Using the *ChemSense* software

- Simplicity (although limited range used)
- Trainees engaged for extended periods (two hours for each process)
- Active discussion of chemical reactions and structures. E.g. for potassium iodide:

*We represented it as covalent but it was dissolved which we decided was ionic.*

# Overall

- New misconceptions beyond age 18: bond angles and episodic thinking

## Reasons?

- Forgetting – or accessing memories
- Multiple frameworks to explain new phenomena (Taber 2000)
- *Mislearned* chemical processes (free atoms, electron shells)

# Using *ChemSense*

- Simplicity
- Engagement – motivation, discussion
- 2-D – other software may be more suitable for 3-D manipulation

# Implications

- Diagnostic
- Extended to formative assessment and development of understanding by addressing misconceptions
- Encouraging dialogue
- Teaching chemistry in schools

<http://www.chemsense.org/>