Coordinating chemistry concepts with problem solving to enhance learning

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Problem

Students fail to coordinate problem solving with core concepts in Chemistry.

Example:

$$2H_2S_{(g)} + O_{2(g)} \text{ <----> } 2S_{(s)} + 2H_2O_{(g)}$$

How will adding O_2 influence the amount of S?

Common errors violate conservation of matter:

- "The addition of O2 would only influence the amount of H2O."
- "Although an increase in O2 will cause the reaction to move forward, it does not affect S"
- "The amount of S does not contain any oxygen, thus it doesn't affect the amount of S."

Approach

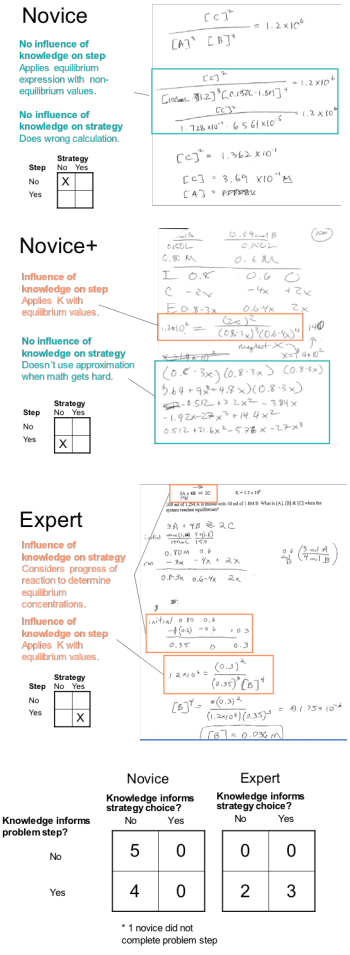
1. Use Cognitive task-analysis to determine how experts and novices differ when solving problems.
2. Develop model of expert knowledge.
3. Test whether instruction that makes coordination of concepts and procedures explicit will enhance learning.

How do experts and novices differ in problem-solving?

Based on verbal protocol study of 5 experts and 10 novices we found:

Experts apply conceptual knowledge both when completing *problem steps* and when choosing and overall *problem-solving strategy.*

Novices carry out calculations without mapping to chemical processes.



Knowledge informs problem step?	Novice: Knowledge informs strategy choice? No	Novice: Knowledge informs strategy choice? Yes	Expert: Knowledge informs strategy choice? No	Expert: Knowledge informs strategy choice? Yes
No	5	0	0	0
Yes	4	0	2	3

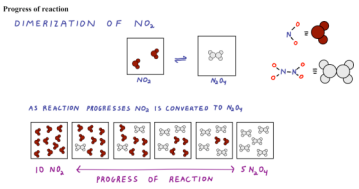
* 1 novice did not complete problem step

What is the model of expert knowledge?

Based on analysis of protocols, experts use a conceptual framework we call the *progress of reaction.*

Progress of reaction

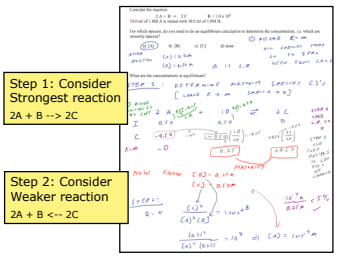
- All possible states of a chemical reaction lie on a continuum
  - From all reactants (left) to all products (right).
- Movement between states is constrained by the chemical reaction
- Forward and reverse reactions may be considered sequentially
  - Though system is dynamic, experts do not consider simultaneous reactions

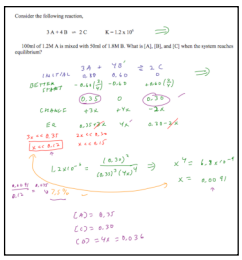


Does instruction that integrates concepts and procedures enhance learning?

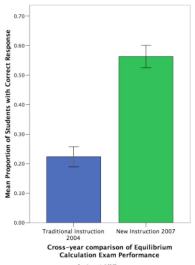
New Instruction
Integrates *progress of reaction* framework with problem solving steps.

Traditional Instruction
Same problem solving steps, but no reference to *progress of reaction.*





Results
Coordination of concepts with procedure led to ~2.5x improvement on problem solving.



Discussion
Coordination of concepts and procedures enhances learning. Problem solving that is grounded in chemical concepts encourages sense making and is more memorable.

The results of this research have informed the design of the Chemical Equilibrium Module of the OLI Chemistry Course.

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