

## A SYSTEMIC APPROACH TO CHEMICAL PROBLEM SOLVING

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# Overview

- Introduction
- Systemic Problem Solving
- Logical problems
- Systemic representation of concepts
- Motivation

## Introduction

Traditionally, problem solving as a process has been presented to students by the teacher in a way that stresses linearity and relies on memorization.

"Textbook solutions to problems and solutions presented by teachers in class are almost always efficient, well-organized paths to correct answers. They represent algorithms developed after repeated solutions of similar problems."

**J. D. Herron, *J. Chem. Educ.*, 1986, 63, 530.**

## What Do The Experts Say?

**Solutions provided in texts represent straight-forward, efficient algorithms**

“They provide no indication of the false starts, dead ends, illogical attempts, and wrong solutions that characterize the efforts of students when they work in problem solving.”

J.D. Herron, *Research in Chemical Education: Results and Directions*, in M. Gardner, et al., (Eds), *Toward a scientific practice of science education*, Erlbaum: Hillsdale, N.J., 1990, p. 35.

**The first stage in problem solving is probably where the solver works hardest trying to understand the problem, extracting relevant information.**

“This is a holistic or gestalt stage where relevant information is ‘disembedded’ from the problem, and the elements of the problem are juggled more or less simultaneously until the problem is ‘restructured’ or transformed into a problem that the student understands”

**Bodner G.M., McMillen T.L.B., *Journal of Research in Science Teaching*, 1986, 23, 727-737.**

## Systemic Problem Solving

"By 'systemic' we mean an arrangement of concepts or issues through interacting systems in which **all relationships between concepts and issues are made explicit to the learner** using a concept map-like representation."

A.F.M. Fahmy, J.J. Lagowski, *Journal of Chemical Education*, 80, 1078 (2003)



*"It's the combination of **making connections between different parts of science and being a teacher.**"*

*Teachers wake up the minds of people - rather than teaching facts, they empower young people to make use of the abilities within them. I am proud of being a good teacher and teaching in many ways."*

*Roald Hoffmann, 2007*

Making connections between different parts of science is important because:

“If nothing has been altered in long-term memory, nothing has been learned.”

W. Schnotz, C. Kürschner, *Educ. Psychol. Rev.*, 2007, 19, 469–508.

## Experts' performances

- Experts spend a great deal of time analyzing a problem qualitatively
- Experts have strong self-monitoring skills

R. Glaser, M.T.H. Chi, Overview. In *The nature of expertise*, M.T.H. Chi, R. Glaser, M.J. Farr, Erlbaum, Hillsdale, NJ, 1988, p. xix-xx.

## Implications

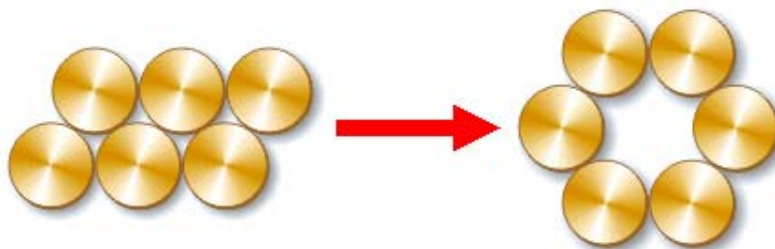
If we want to help our students, we have to find a different way to teach problem solving, a way that obliges students to spend more time analyzing the problem.

The initial problems tackled were non-chemical and non-algorithmic to emphasise the analysis and synthesis operations without the interference of chemical concepts which students may not have mastered as yet.

## Logical problems

### How Many Coin Moves Are Needed?

A move consists of sliding one coin to a new position, where the moved coin must touch two other coins, and no other coins are allowed to move.

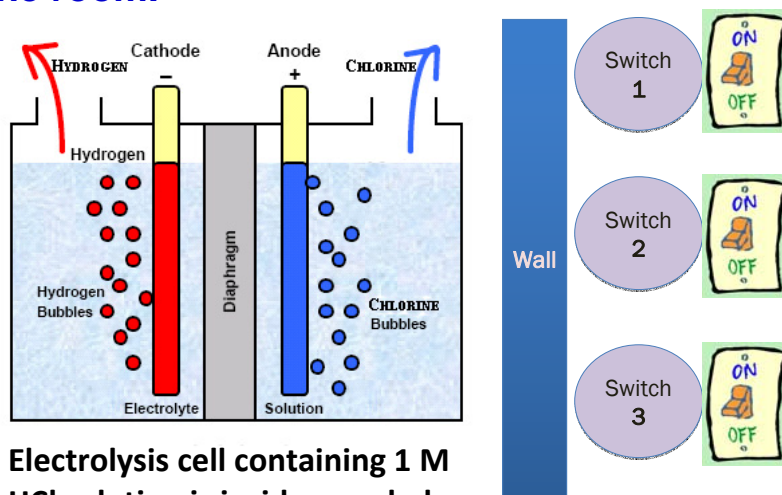


## The Richard Zare's Problem

An aqueous solution of hydrochloric acid is electrolyzed, causing the release of hydrogen gas at one electrode and chlorine gas at the other electrode.

This electrolytic cell is placed in a closed, sealed room having only one entrance. Wires lead to the electrodes and there are three switches outside the room, but only one switch is connected to the electrolysis cell.

You are allowed to play with the switches all you want, turning them on and off, before entering the room.



Electrolysis cell containing 1 M HCl solution is inside a sealed room having one closed door

## The Richard Zare's Problem

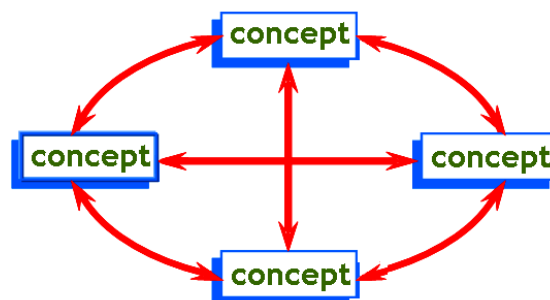
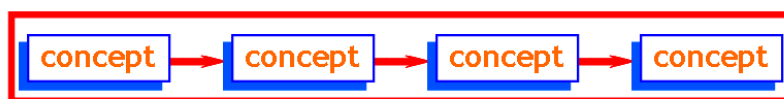
Initially all switches are in the off position, as shown in the diagram.



You are allowed to enter the room only once.

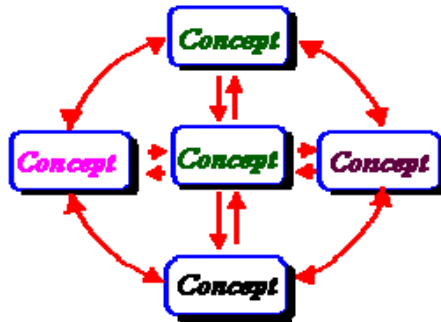
How do you determine which of the three switches is connected to the electrolysis cell?

## Systemic representation of concepts



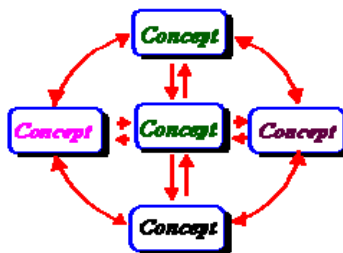
## How the Teacher Can Make a Difference

The essential hallmark of a systemic approach is **meaningful learning**, contrasted with learning by rote.



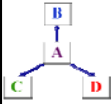
Our students need to have a global view of the relationships between the concepts.

## How the Teacher Can Make a Difference

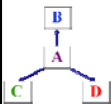


After every lesson I send a list of the day concepts to my students, for studying and drawing the concept map.

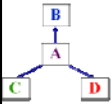
## Tools for meaningful learning



**Concept mapping**



**Active learning approaches**



**Problem solving methods**

## *The Power of Motivation*

### **Motivation:**

Factors within and outside an organism that cause it to behave a certain way at a certain time

## **Shulman's Table of Learning:**

- **Engagement and Motivation**
- **Knowledge and Understanding**
- **Performance and Action**
- **Reflection and Critique**
- **Judgment and Design**
- **Commitment and Identity**

L.S. Shulman, Making Differences: A Table of Learning, *Change*, 34, 36 (2002)

### **The Teacher Can Make a Difference**

**Offering a supportive environment where commitment, enthusiasm for learning, and students' success are important**

**HOW ?**

**By personal example**

## How the Teacher Can Make a Difference

In the very first lesson,

- I collect the names of the students (to make CL groups)
- express my enthusiasm for learning
- voice my expectations that all students will learn much
- I learn their names and always I call someone by name
- many will learn ways of approaching problems that will carry over to all their other studies

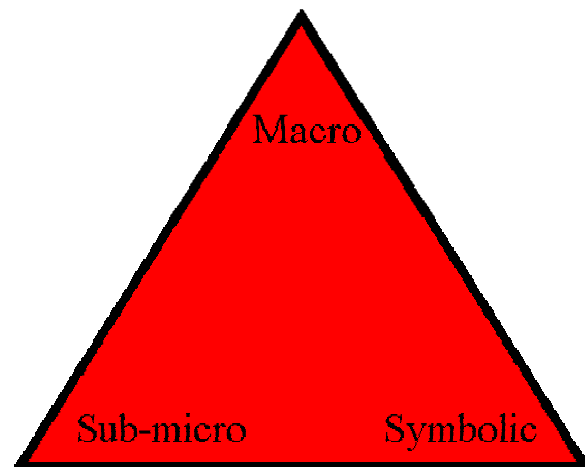
To learn meaningfully is similar to climb

a mountain

It is a  
difficult  
task

A great effort is  
necessary

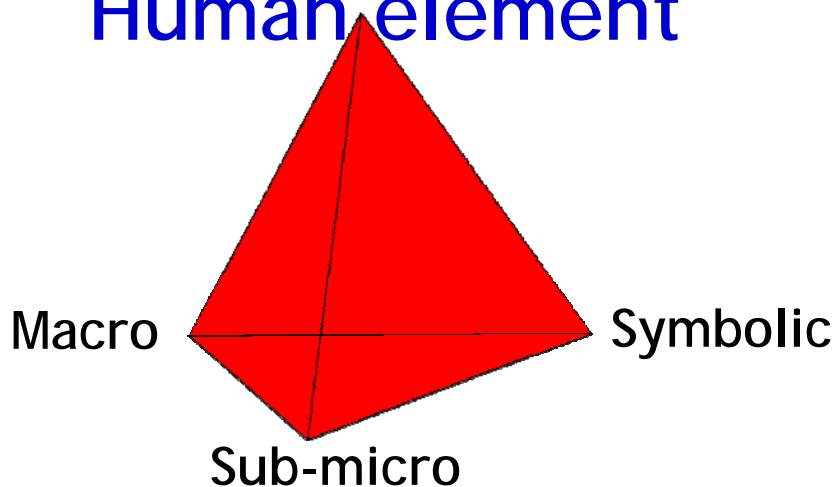
## The Chemistry Triangle



Johnstone A.H., *Journal of Computer Assisted Learning*, 1991, 7, 75-83.

## The Human Element

Human element



## Didactic in numbers



**1,250 concept maps + 10,550  
problems & 720 emails**

**"Inspiration is more  
important than  
information"**



**Dick Zare**  
Stanford University

# Thank you

for your  
attention !

