Educating Science Students About Education

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JSC 301 HIS
Principles & Practices in Science Education

Dr. David C. Stone (Chemistry)
Prof. Jim Colliander (Mathematics)
http://www.chem.utoronto.ca/coursenotes/JSC301/

- 12 weeks, 2 lecture hours/week
- Enrolment in STEM program
- Minimum 8.0 credits (3rd year+)
- Counts as social sciences breadth credit
- Includes project and/or placement
- First offered in 2012-13

Participants (22 students):
- Biochemistry
- Biology
- Chemistry
- Environmental Science
- Health & Disease
- Human Biology
- Human Geography
- Psychology
- CTEP (Christianity & Culture)

Course Outline:

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<tr>
<th>Unit</th>
<th>Subject</th>
<th>Topics</th>
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<tbody>
<tr>
<td>1</td>
<td>Knowledge, teaching, &amp; learning</td>
<td>Constructivism, development, memory, taxonomies</td>
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<td>2</td>
<td>Curriculum, planning, &amp; assessing</td>
<td>Ontario science curriculum, learning activities &amp; outcomes</td>
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<td>3</td>
<td>Practical considerations</td>
<td>Misconceptions, threshold concepts, learning styles, media</td>
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<td>4</td>
<td>Project development &amp; presentation</td>
<td>Various; guest presentations (large class teaching, science outreach, demonstrations)</td>
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First offered in 2012-13
Schema/schemata:
- Knowledge “lego bricks”

Expert

Rich
Persistant
Connected

Novice

Sparse
Transitory
Unconnected

Patricia K. Cross, "Learning is about making connections"
The Cross Papers Number 3 1999, publ. League for Innovation in the Community College, available via ERIC/EDRS

Things to do:
- Without consulting the internet, a text, or lecture notes, draw as completely as possible (and bring with you next week):
  - a concept map for one key STEM concept from your primary subject area
  - a concept map for one key STEM concept from a subject outside your expertise

Learning process:

Inputs

visual
auditory
motor
tactile
olfactory

Perceptual
filter

Working memory
(limited)

- store
- compare
- manipulate
- interpret
- process
- prepare for storage

Long-term memory

Perceptual filter feedback loop

Working memory:
- In your head, convert the date to numbers and rank them in ascending order:
  - 137 - seventeenth march
  - 0123 - twenty-third october
  - 014589 - fifteenth april eighty-nine
  - 12467899 - twenty-sixth september nineteen eighty-seven
  - 11122489 - nineteenth december eighteen twenty-four
Ways of knowing:

- SOLO (Biggs & Collis)
  - Extended abstract
  - Committed relativist

- Perry (simplified)
  - Dualist
  - Relativist
  - Conceptual
  - Relational
  - Multiplist

- Conceptual
  - Analyse
  - Evaluate
  - Recall

- Algorithmic
  - Apply
  - Understand
  - Remember

- Bloom (revised) (simplified)
  - Create
  - Recalling

Pre-Sputnik:

- Ontario curriculum S-17, 1952 (grade 11-12)

  - Chemistry
    - Changes of state (2 weeks)
      - The three states of matter and their general characteristics.
      - Melting and freezing, illustrated by water and ice cubes.
      - Melting points as characteristic physical constants.
      - Evaporation and condensation, illustrated by water or carbon tetrachloride.
      - Boiling points as characteristic physical constants.
      - Influence of pressure on boiling points.
      - Sublimation, illustrated by iodine, benzoic acid or naphthalene.
      - Effects of temperature on rate of evaporation of water.
      - Effect of humidity.
      - Changes in volume and energy accompanying changes of state.
      - Explanation of changes of state in terms of the molecular theory of matter.
    - It should be stated that individually distinct molecular particles are not thought to exist under ordinary conditions for such substances as metals, salts, dissolved, etc.

- The use of characteristic physical properties (density, melting point, boiling point, ability to form solution, etc.) for identification of substances.

Post-Sputnik:

- Ontario curriculum S-17D, 1966 (grade 12)

  - Unit I: Introduction (1 1/2 weeks)
    1. Scope of chemistry and its relationship with other science and mathematics
    2. The chemistry of water as made up of a definite number of pure substances, sometimes occurring isolated, but more often occurring in mixtures
    3. Properties as characteristics which identify pure substances, e.g., colour, density, boiling point, melting point, conductivity of electricity, etc.
    4. Classification of pure substances as elements (characteristics, including reference to limit of decomposibility) or compounds (characteristics, including constant composition)
    5. Physical change and chemical change
       - Syllabus and decompositions
      - Experiments
        - (a) Boiling point of water, or carbon tetrachloride, or methanol
        - (b) Melting point of paraffin, or paracetamol.
        - (c) Quantitative determination of various samples of purity (I) scale
        - (d) Synthesis of sulphides (copper and zinc)

  - Unit II: The Structure of Individual Atoms (1 1/2 weeks)

    - Note: Students should be trained in the recognition and use of symbols of the elements, e.g., Fe, and of individual substances, e.g., CuO, C12H22.
    1. Fundamental Particles: electron, proton, neutron
      - (a) Absolute mass
      - (b) Approximate scale of atomic masses, based on proton or neutron as unity
      - (c) Charge
      - (d) Approximate size
    2. The Atom
      - (a) Nucleus (Bohr, Rutherford)
      - (b) Atomic number and mass number
      - (c) Electron arrangements, e.g., 2, 8, 8, 2 (Note: One-order elements only occupy the first twenty)
      - (d) Schematic diagram of atom (atomic number 1 to 20) from given atomic numbers and mass numbers
      - (e) Isotopes
        - (i) Occurrence of different forms of the same element, differing in mass number
        - (ii) Constancy or near-constancy of isotopic composition in nature
        - (iii) Atomic weight of an element from the mass and relative abundance of its isotopic forms
        - (iv) Precise definition of the atomic weight scale in terms of carbon-12

Science 1999

- "It cannot be too strongly emphasized that the aim of the course is to create an understanding of the subject, rather than to provide information to be memorized."
  - (Grade 12 chemistry, p.1)

- "The [grade 9-12 program] is designed to promote these goals:
  - to understand the basic concepts of science
  - to develop the skills, strategies, and habits of mind required for scientific inquiry
  - to relate science to technology, society, and the environment"
  - (Grade 9/10 Science, p.4)

Robert D. Gidney
U of T Press
Troublesome Knowledge

- Perkins (1999):

“Some students will resort to rote memory and routine procedures ... They will try to learn enough ... to pass the test without developing any real insider feel. And pass they may, ending up with knowledge troubled by partial and brittle understandings...”

- Ritual
- Inert
- Conceptually difficult
- Foreign or alien
- Tacit (assumed)


Stumbling blocks:

- Rosalind Driver
  - Ideas about science that are
    - incorrect
    - ingrained
    - impervious

Alternative conceptions:

- Vincente Talanquer:

“[alternative conceptions] seem to result from the confident and impulsive application of a crude, incomplete, limited, and superficial explanatory framework about chemical substances and phenomena. This knowledge system ... creates the illusion of explanatory depth: students believe that they understand more than they actually do.”

Origin of alternative conceptions:

- An atom is…
  - Smallest object that retains the properties of an element (common)
  - Smallest unit of an element, having all the characteristics of that element
  - Smallest part of an element that can exist chemically (Oxford Dictionary of Chemistry)
  - Smallest particle still characterizing a chemical element

(Student projects:

- Grade 3 science - Growth & Changes in Plants
- Grade 7 & 8 science - A Pure Substances & Mixtures Mixer
- - Zombie Cell Apocalypse
- Grade 11 biology - The Genetics of Blood Types
- Grade 11 chemistry - Bonding with Bonding
- - Freezing Point Depression: Ice Cream!
- - The Game of Life Chemistry
- Grade 11 physics - Newton’s Laws by Experiment
- Grade 12 biology - Career Exploration: Building a Wiki
- - Microarray and Cancer Detection

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