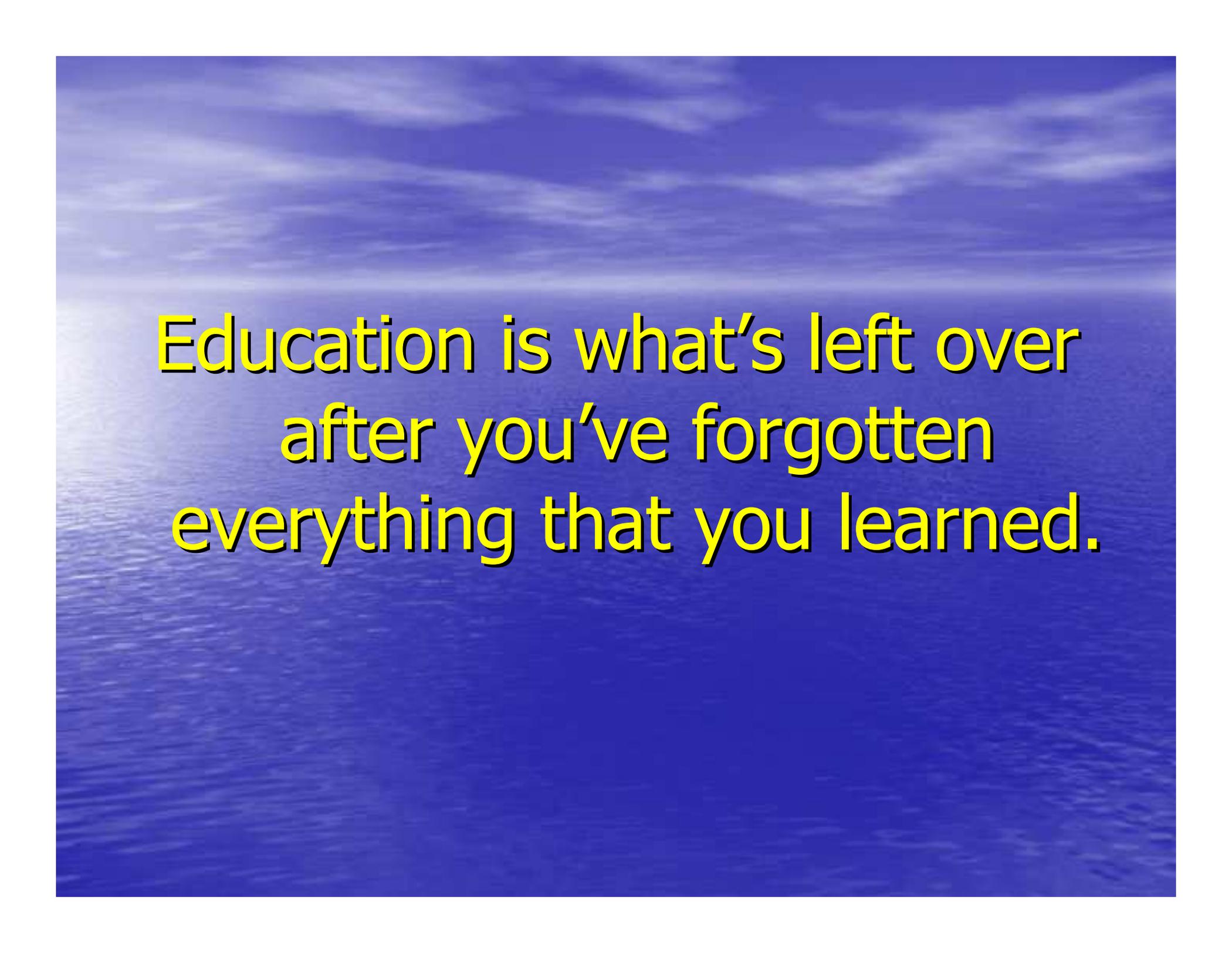


# Incorporating Discovery-Based Experiences into the Science Curriculum

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# Three Goals Today

- Broader Learning Outcomes
- Cooperative Learning in the Classroom
- Project-based Laboratories



Education is what's left over  
after you've forgotten  
everything that you learned.

# Desired Learning Outcomes

- *Knowledge outcomes* – “..particular areas of **disciplinary or professional content** that students can **recall, relate, and appropriately deploy.**”
- *Skills outcomes* – “the learned capacity to do something – for example, think critically, communicate effectively, productively collaborate, or **perform particular technical procedures** – as either an end in itself or as a prerequisite for further development

- Affective Outcomes – “..usually involve changes in beliefs or in the development of particular values, for example, empathy, ethical behavior, self respect, or respect for others.”
- Learned abilities – “..typically involve the integration of knowledge, skills, and attitudes in complex ways that require multiple elements of learning. Examples embrace leadership, teamwork, effective problem-solving, and reflective practice”

From Ewell, P.T., *Accreditation and Student Learning Outcomes: A Proposed Point of Departure*, Council for Higher Education Accreditation (CHEA) Occasional Paper, Washington, DC, September 2001

# Topics Not in My Undergraduate Notes (circa 1976)

- Fused silica columns in GC
- Bonded phases in LC
- Capillary electrophoresis
- High-field NMR – multidimensional methods
- Inductively coupled plasma
- Mass spectrometry of proteins
- Microelectrodes in electrochemistry

By its nature, cooperative and project-based learning will involve the development of content and laboratory skills

Decide what content/skills you would like to be included and design activities that include those content/skills

# My Individual Courses

- General Chemistry

"General Chemistry: Expanding the Learning Outcomes and Promoting Interdisciplinary Connections through the Use of a Semester-long Project," Wenzel, T. J., *Cell Biology Education*, in press.

"General Chemistry: Expanding the Goals Beyond Content and Lab Skills," Wenzel, T. J.; in *Gender, Science and the Undergraduate Curriculum: Building Two Way Streets*, Association of American Colleges and Universities, **2001**, 29-46.

- Upper-level separations course

"The Teaching Learning Process in Analytical Chemistry," Wenzel, T. J.; *Microchimica Acta*, **2003**, 142, 161-166.

"A New Approach to Undergraduate Analytical Chemistry," Wenzel, T.J.; *Analytical Chemistry*, **1995**, 67, 470A-475A.

# Cooperative Learning

- Class divided into small groups (3-5)
- Presented with a problem or question
  - I serve as a facilitator
  - If one student sees the point, she or he is to explain it to the others
  - When the groups appreciate the point, I call timeout and highlight the concept

# Advantages of Cooperative Learning

- More “teacher” resources because the students are teachers as well
- Less formal
- Active learning – I know what they do/don’t understand – they know what they do/don’t understand
- Students spend more time on class material
- Cooperation, not competition
- Students learn more

# Outcomes of Cooperative Learning from Prior Research Studies

- Statistically significant improvements in academic achievement
- Better reasoning and critical thinking skills
- Proposed more new ideas when presented with problems
- Transferred more of what was learned in prior situations to new problems
- Reduced levels of stress
- Promotes more positive attitudes toward subject and instructional experience – faculty get to know students better

- Decreased absenteeism
- Improved student commitment
- Greater motivation toward learning
- Better student retention (especially for women and minorities)
  - Socially involved
  - Academically involved

"Peer-Assessment and Self-Assessment of Group Activities," Wenzel, T. J., *Journal of Chemical Education*, in press.

"Practical Tips for Cooperative Learning," Wenzel, T. J., *Analytical Chemistry*, **2000**, *72*, 359A-361A.

"Cooperative Student Activities as Learning Devices," Wenzel, T. J., *Analytical Chemistry*, **2000**, *72*, 293A-296A.

"Cooperative Group Learning in Undergraduate Analytical Chemistry," Wenzel, T.J., *Analytical Chemistry*, **1998**, *70*, 790A-795A.

## Chem 212 – In-class problem set #1

1. Calculate the pH of a solution that is 0.155 M in ammonia.
2. Calculate the pH of a solution that is 0.147 M in pyridine and 0.189 M in pyridinium chloride.
3. Calculate the pH of a solution that is 0.332 M in anilinium iodide.
4. Calculate the pH of a solution that is prepared by mixing 45 ml of 0.224 M chlorobenzoic (3-) acid with 30 ml of 0.187 M ethylamine.
5. Calculate the pH of a solution that is prepared by mixing 75 ml of 0.088 M aniline with 50 ml of 0.097 M nitrophenol (2-).
6. What is the typical range of  $K_a$  and  $K_b$  values for weak acids and bases? Which value represents the weakest and which the largest? What would be the pH of solutions 0.1 M in the acid or base at the extremes of the range?

## Chem 212 – In-class problems – Chromatography set #4 – **Ion-Exchange Chromatography**

1. Describe a scheme using ion exchange chromatography that would enable you to deionize water. Say something about the capacity of the ion exchange resins you would use for this purpose.
2. Would ion exchange resins that are useful for deionizing water be useful for analytical separations?
3. What would be the order of retention for the ions Li(I), Na(I), and K(I) on a cation exchange resin? Justify your answer.
4. Consider the case of separating the alkali ions in (3) on a polystyrene resin using a fairly dilute solution of hydrochloric acid as the mobile phase.
  - a) What is the bound ion and mobile counter ion?
  - b) One problem is how to detect these ions. They do not absorb ultraviolet or visible light in the accessible portion of the spectrum. They do not absorb infrared light. Conductivity might work except that the hydrochloric acid in the mobile phase produces too high a background signal. Devise a way to remove the conductivity of the eluent ions (HCl) but retain the conductivity of the alkali ions you wish to detect.

## Chem 107B – Structure of Atoms

Each group is to talk about your current knowledge of the structure of atoms. Some things you might consider include:

What important fundamental particles make up atoms?

Do these particles have charges? If so, what are the charges?

How are those particles arranged in atoms?

Suppose you had to explain what an atom looked like to a 10 year old. Draw a picture that would help in your explanation.

Are there any things you simplified in your picture?

## Chem 107B – Electronic configurations

1. Write the electronic configuration for carbon (element 6).

Consider the last two electrons in the carbon configuration. Do you see how there are two different ways in which the electrons could be situated? Make sure you understand the difference between the two ways.

It is possible to measure whether an atom has unpaired electrons or not. Atoms with unpaired electrons interact with a magnetic field whereas those with all the electrons paired do not. By measuring the specifics of the interaction with the magnetic field, it is even possible to determine the number of unpaired electrons in an atom. For carbon, it has been determined that each atom has two unpaired electrons. Does this agree with one of the possible configurations?

**NOTE:** Atoms or molecules with unpaired electrons are said to be **PARAMAGNETIC**. Those with all the electrons paired are said to be **DIAMAGNETIC**.

Use the information observed with carbon to develop a generalization for the filling in of electrons into orbitals with the same energy. This generalization holds all the time and is referred to as the Aufbau principle.

## Chem 107B - Worksheet on Electronegativity, Ionization Energies, Electron Affinities, and Atomic Radii

1. Electronegativity: The electronegativity expresses how much a particular element wants an electron. The higher the value, the more that particular atom wants an electron.

The following page has a periodic table that lists the electronegativities of each element. The absolute values do not have meaning. What does have meaning is the relative values. Note that the noble gases (He, Ne, Ar, ...) are not included since these elements have stable configurations and do not want to gain electrons.

A) Examine the electronegativities of the halogens (F, Cl, Br, and I). Is there a trend? If so, propose an explanation that would justify the trend.

B) Examine the electronegativities for the period that includes the elements lithium (Li) through fluorine (F). Is there a trend? If so, propose an explanation that would justify the trend.

# Continuum of Scientific Inquiry

- Level 0
  - Problem area, methods of solution and “correct” interpretations are given or immediately obvious from either statements or questions in the student’s laboratory manual or textbook. Includes activities in which students simply observe or “experience” some unfamiliar phenomena or learn to master a particular laboratory technique.

# Continuum of Scientific Inquiry (con't)

- Level 1
  - Laboratory manual proposes problems and describes ways and means by which the student can discover relationships he/she does not already know from manuals and texts
- Level 2
  - Problems are provided, but methods as well as solutions are left open

# Continuum of Scientific Inquiry (con't)

- Level 3

- Problems, as well as solutions and methods, are left open. The student is confronted with the “raw” phenomenon

(Adapted from Schwab, 1964; Herron, 1971)

(Also from Lederman, Ill. Inst. Tech.)

# Continuum of Scientific Inquiry

<u>Level</u>	<u>Problem/Question</u>	<u>Procedure</u>	<u>Solution</u>
0	Given	Given	Given
1	Given	Given	Student
2	Given	Student	Student
3	Student	Student	Student

# Introductory Course

- Thematic version of general chemistry – fundamentals of chemistry related to the study of the environment
- Counts for the chemistry major
- Pre-requisite for all upper-level chemistry courses
- 60 students in class (20/lab)

# Course Goals

- Learn fundamental concepts of chemistry
- Learn that science does not know all the answers
- Participate in and learn about the process through which scientists undertake investigations and create knowledge
- Learn in interaction with, rather than in isolation from, other students
- Appreciate that science occurs in a social context

# Laboratory Project – Groups of 4

- Do plants grown in soil contaminated with lead take up more lead?
- Does the uptake of lead vary with the acidity of the rain water?

# Some questions the students need to answer:

- What to grow?
- What soil to use?
- How to mimic acid rain?
- How much lead to add?
- What watering schedule?
- What to use as a control?

# Some advantages of the project:

- Conduct a real investigation
- Ask/answer questions
- Design experiments
- Unanticipated problems
- Teamwork
- Communication – Informal/formal
- Opportunity for leadership

# Uncertainty

- 26 of 29 contaminated samples had higher lead
  - other three?
- Acidity trend is inconclusive

# Separation Science Course

- Analysis of methylbenzenes/terpenes in air
- Analysis of trihalomethanes in drinking water
- Amino acid content of foods (popcorn and beer)
- Caffeine, theophylline, and theobromine levels in chocolate
- Analysis of nitrate and nitrite in hot dogs/cured meats
- PAHs in burgers, oysters, diesel exhaust and wood smoke
- Toxic metals in sludges from waste-water treatment plants

- Groups of 2 or 3 – one project per group
- Proposal five weeks into the term
- 30 hours of minimum lab time (excluding writing of final report)
- Individually written final reports
- Final oral presentations - Powerpoint

## Emphasizes the entirety of the analytical process – a real sense of analytical chemistry

- define the problem
- search the literature
- make decisions (sampling, workup, etc.)
- collect samples
- perform the analysis
- interpret data/draw conclusions
- present the findings – oral and written

- So, what do we do?  
Scifinder Scholar search
- Team work/communication/leadership  
 $3 \times 30 = 90$  hours
- Ability to work “off hours”  
6 am air sampling  
Most work far more than 30 hours
- Problem solving  
Unanticipated problems
- Independence/empowerment – Three-room problem

- No group completes their project, but they appreciate the process of analytical chemistry
  - Sampling
  - Sample workup
  - Standards
  - Reproducibility
  - Accuracy/reliability
- Appreciated how difficult it is to obtain a good analytical number, especially when performing trace analysis
- Ask/answer questions
- Experimental design
- Success from failure

# Other Programs

- Arizona - Materials Characterization Project (Jeanne Pemberton)
- Kansas - Environmental/industrial/consultants (George Wilson)
- Medgar Evers College - Urban air/community projects (Wilbert Hope)
- Howard University - Community service projects (Charles Hosten)
- Loyola-Chicago - Lead in the environment – community connections (Alanah Fitch)
- Northeastern University - Bioanalytical chemistry (Pam Mabrouk)
- U. Central Arkansas - Blood plasma (Cameron Dorey)
- Union College - Water quality – Trout Unlimited (Tom Werner)
- Oberlin/Wooster College - Forensics (Bob Thompson)