Real Work is better than Homework

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Context

1994 ACS HS pt A (40q)

30\textsuperscript{th}-ile 70\textsuperscript{th}-ile

13\% 55\% 32\%

E Earns Gen Chem & Lab Credit

Logistics: 1400
35% AP
> 70th-ile
55% 1st Yr

4 faculty instructors
10-12 GSIs
80-90 peer led groups

Organic I
Intro Lab
Organic II
Org Lab

Organic First at the University of Michigan
Ege, Coppola, Lawton JCE 1997, 74 74-83.
Coppola, Ege, Lawton JCE 1997, 74 84-94.

The discipline liberates!
Coppola & Krajcik JRST 2013, 50 (6), 627-638.
Coppola, Chem. Educator 1996, 1 (5)

(1) atoms are conserved
(2) reactions are not explosions
(3) main group is well behaved

$\text{H}_3\text{C} = \text{CH}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{Cl} + \ ?$

$\text{H}_2\text{O} + \text{H}_2\text{Cl} \rightarrow \ ?$
1989-2015

- 1700 students
- 65% Eng
- 30-70th-ile
- 95% 1st Yr

- 1400 students
- 35% AP
- > 70th-ile
- 55% 1st Yr

Gen Prin
Gen Lab
~350

Organic I
Intro Lab

Organic II
Org Lab

intro p-chem
(bio)inorg I

(bio)analytical
analyt lab

synth/char
phys method

~250 majors per year in 6 degree programs

The hidden curriculum

Complete the following reaction sequences as required.

(a) *ACS Med Chem Lett* 2014 5 1230 (modified)

\[
\begin{align*}
\text{NH}_2 \quad \text{H}_2\text{C} \quad \text{N} \quad \text{O} \quad \text{CH}_3 \\
\text{H}_2\text{C} \quad \text{N} \quad \text{O} \quad \text{CH}_3 \\
\end{align*}
\]

\[
\begin{align*}
\text{NH}_2 \quad \text{H}_2\text{C} \quad \text{N} \quad \text{O} \quad \text{CH}_3 \\
\text{H}_2\text{C} \quad \text{N} \quad \text{O} \quad \text{CH}_3 \\
\end{align*}
\]

\[
\begin{align*}
\text{NH}_2 \quad \text{H}_2\text{C} \quad \text{N} \quad \text{O} \quad \text{CH}_3 \\
\text{H}_2\text{C} \quad \text{N} \quad \text{O} \quad \text{CH}_3 \\
\end{align*}
\]

\[
\begin{align*}
\text{NH}_2 \quad \text{H}_2\text{C} \quad \text{N} \quad \text{O} \quad \text{CH}_3 \\
\text{H}_2\text{C} \quad \text{N} \quad \text{O} \quad \text{CH}_3 \\
\end{align*}
\]

Hint: the two substitution reactions take place in a specific and predictable order, to produce a single product.

(b) *ACS Med Chem Lett* 2014 5 462

\[
\begin{align*}
\text{C}_{15}\text{H}_{16}\text{N}_{2}\text{O}_{4} \\
\end{align*}
\]

1) \( \text{SOCl}_2 \) with \( \text{H}_3\text{C} \text{N} \text{OCH}_3 \) and \( \text{BrMgC} \text{H}_3 \)
2) \( \text{H}_2\text{O} \) workup

Real Work Design Principles

• balance of convergent & divergent assignments
• balance of teamwork & individual work
• use authentic texts (literature) & evidence
• peer presentation, review, and critique
• students use the instructional technologies
• as important to the class as the teacher’s work

SUPPLEMENTAL INSTRUCTION
“STUDIO” FOR SCIENCE-MOTIVATED

Structured Study Groups

Scale: 160 students
2 added hours/week
8 peer-led groups ~20
**WEEK #1**

**Divergent Task:**
find molecule C_{13-15}H_yHet_{1-3}
give the citation
invent 5 rational isomers
rank your invented molecules
by melting point
by boiling point
by dipole moment
by water solubility
explain ranking (write out)
160 DIFFERENT REPLIES
goals: explain & defend

**In the Group Session:**
peer review & discussion
a chance to change/correct

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**WEEK #3**

Create a quiz/exam problem from a literature source appropriate for the class.

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**Synthetic Routes to Fluorescent Dyes Exhibiting Large Stokes Shifts**
Sandra Ruhn, Pascal Retallack, Antonette De Nicola, Gilles Ulrich, and Raymond Ziesler

**ABSTRACT:** Determination of kinetic 2-(4-hydroxystyryl)-4,4-dimethylethano-1,3,5-triamines have been synthesized in high yields in a controlled manner using a metalating reaction sequence. Induction of either 3-(4'-
hydroxystyryl)-1,3,5-triamine or 3-(4'-iodo-4'-methylenepent-2'-yl)-
4,4-dimethyloctahydropyrido-1,3,5-triamine with 1,2-proline provides species differing in the positioning of the hetero group relative to the fluorophore which modify shading bonds. These compounds and metal complexes under UV/VIS analysis. Thus, fluorescent, hemi- and 1,3,4-ethynol-heterobenzene groups have been directly grafted, while unsubstituted polymeric aromatics such as pyren and pyrene have been linked via alkyne bridges, as have ethylene/fluorenes/dithiironamantanes (DSSP) dye prepared in situ. The presence of a hydrogen bond in the ground state involving the hydroxy substituent has been established by proton NMR, and several X-ray structural determinations. All of the non-dyes with a simple substituent (phenyl, thiophene) exhibited a pronounced ground-state fluorescence resulting from an intramolecular proton transfer in the excited state (ESIP) which produces a large Stokes shift (ΔS > 6000 cm^{-1}). With other dyes, the fluorescence of the latter form responsible for the ESIP process could be used as the input energy in efficient intramolecular range transfer processes, replacing pristine with ground allowed several of the direction of energy transfer from the polymeric module to the latter form.
Month-long projects: weekly milestones, presentations, reviews

IV.  (40 points)
The following transformation was recently reported (Org. Lett. 2000, 2, 3893).

The following transformation name for Compound K?

(a) What is the IUPAC name for Compound K?

(b) What is the hybridization at each of the indicated carbon atoms?

(c) Draw a 3-dimensional orbital picture for Compound K using lines, dashes and wedges to indicate the sigma bonds, and overlapped p-orbitals for the pi bonds (you may leave the methyl groups indicated as “CH3” in your picture.

(d) Provide a complete, step-wise mechanism for the formation of Compound L from Compound K.

Another example of student-generated instructional materials

E-homework: not used in UM Organic
- promotes authoritative answers
- replaces peer interaction

Goal: 100 great skill-based problems in each of 10 areas with a merciless tutor to bridge text/test gap?

A. In 1912, Carl Mannich, a Professor of Pharmaceutical Chemistry at the University of Göttingen, published a paper on a reaction that would come to bear his name: The Mannich Reaction (Archiv der Pharmazie 1912, 250, 647). In the following problem, (a) provide the structure of the intermediate (A) that results from the curved arrows shown. Then, (b) using your intermediate, provide the arrows that are needed when intermediate A reacts with acetone enolate to give the observed products.

draw the structure of A and the arrows for its reaction with acetone enolate
Another example of student-generated instructional materials

**E-homework:** not used in UM Organic
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**Goal:** 100 great skill-based problems in
each of 10 areas with a merciless tutor to bridge text/test gap?

Fall: train 170 students to author 200 probs.
Spring: select 31 to generate 2 prob./week
Summer: test 750 problems/10 skill areas
Fall: implement with 1500 students
  - new: edit Org 1 on feedback
  - new: generate Org 2
Baseline item analysis to monitor

Another example of student-generated instructional materials

120 students (second term)
5 sections of ~25...
teach teams of 2-3 get a step

- present mechanism
- animate mechanism
- correlate spectral data
- annotate experimental
- answer leading questions

Create multimedia text

- final exam on student text
Laboratory courses are a never-ending challenge.

SKILLS versus INQUIRY

“Who has the same solid material as you do?”

“Who has the same... liquid?
... acid concentration?
... numerical series?
... dynasty artifact?
... enzyme activity?
... inhibitor concentration?”

Techniques for gathering information:
melting point, solubility, tlc, IR

Coppola, Lawton 1995, 72, 1120-1122
Laboratory courses are a never-ending challenge.

**SKILLS versus INQUIRY**

Week 1: Here are 25 substances, create and separate a binary mixture (600 combinations).

Week 2: refine your procedure, purify your compounds. Write up a procedure. Make a couple of samples.

Week 3: exchange samples, test others’ procedures.

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**RESEARCH-DRIVEN**

Week 1: reproduce a literature result (hand out the paper, buy the substrates)

Week 2: test some unreported substrates, write up results

Week 3: exchange samples, are the results reproducible?

Next year: don’t do the same thing
Laboratory courses are a never-ending challenge.

RESEARCH-DRIVEN

Is there a simple procedure being carried out that has not been optimized for yield?

\[
\begin{align*}
\text{5-Nitroindole} & \xrightarrow{\text{Na/EtOH}} \text{3-Nitroindole} \\
& \xrightarrow{\text{EtOAc}} 35\%
\end{align*}
\]

Week 1: replicate literature result
Week 2: conduct study
Next year: build on results

- temperature profile team
- base concentration profile team
- co-solvent profile team
- stoichiometry profile team
The Interdisciplinary Challenge

Core Expertise

**Combined PhD in Chemistry & Education**

**Prof. Mark M Banaszak-Holl**

“research group” on drug transport based on gathering together & organizing the desired set of core expertise

**MS in Postsecondary Education for future faculty PhDs**

**Drug Transport Agents**

structure of the functionalized agents mechanism of cell incorporation mechanism of drug release ultrastructural aspects of cell apoptosis

**Stand-alone PhD in Chemistry**

**Macromolecular Science & Engineering**

Medical Nanotechnology

Physics

The historical development of understanding the alcohol dehydrogenase mechanism

**Week 1:** Enzymatic transfer of hydrogen

(J Biol Chem 1953, 202, 687)

**Week 2:** Substituent & isotope effects in yeast ADH reaction

(J Biol Chem 1972, 247, 7917)

**Week 3:** X-ray structure of active site & mechanism for substrate specificity

(J Biol Chem 1997, 272, 18588)

**Week 4:** ADH activity & blood alcohol in women

(NE J Med1990, 332, 98)
The Interdisciplinary Challenge


The only thing that matters: How to support the work?

US Big Science since 1950

Research Groups:
Big ideas get implemented via an intergenerational training structure.


UM Chemistry 1994-2015

Teaching Groups:
Big ideas get implemented via an intergenerational training structure.

Coppola, B. P.; Banaszak Holl, M. M.; Karbstein, K. ACS Chemical Biology “Closing the Gap Between Interdisciplinary Research and Disciplinary Teaching” 2007, 2(8), 518-520.

2014: hard line budget & a new Associate Chair position

Dual-Mentorship Post-doc
• minimum steady-state of 8/yr
• recruited into research groups
• 1 course/year

PhD students
• FFGSI (10 hr/wk fellowship)
• 2 cognates in education
• MS Post-Sec Science Education
• integrate into thesis

Undergraduates
• positions in the teaching program
• lots of entry points for credit/$$

“Our research focuses on the design and synthesis of novel organic materials…. Prof. McNeil is also active in a number of education initiatives.”

Professor Anne McNeil

HHMI Professor, 2015
Camille Dreyfus Teacher-Scholar Award, 2012 LSA Excellence in Education Award, 2011 NSF Career Award, 2010 PECASE Award - Presidential Early Career Awards for Scientists and Engineers, 2010 Beckman Young Investigator Award, 2009 Chemistry Faculty Research Award, 2009 Office of Naval Research Young Investigator Award, 2009 Seyhan N. Ege Junior Faculty Award, 2009 Thieme Chemistry Journal Award, Synthesis and Synlett, 2009 Elizabeth Caroline Crosby Research Award, 2008 William R. Roush Junior Faculty Career Development Award, 2008
**Integrating Wikipedia Editing into Graduate Courses**

Professors McNeil & Coppola
Cheryl Moy, Jonas Locke, grad students

- create/test instructional materials
- interface with Wiki Central
- training & monitoring of class
- collecting assessment data
- extension to other graduate classes
- grow institutional support


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**Studio Instruction: General Chemistry**
- “one-room schoolhouse”
- integrated lab/lecture/discussion

Mark Banaszak-Holl
Professor of Chemistry
Professor of Macromolecular Science and Engineering, College of Engineering

2013: Top 25 STEM Professors in MI

Active research projects within the group include:
- studies on gene and drug delivery
- nanoparticle toxicity
- nanoscale collagen structure
- organometallic chemistry
- chemical education research
**Studio Instruction:** General Chemistry
- “one-room schoolhouse”
- integrated lab/lecture/discussion

**5-year experiment:** taking lab & lecture at the same time is better than separately, but the academic measures for studio vs. co-enrollment show no differences. Some gains observed for URM students.

Professors Banaszak-Holl, Krajcik, Rothman, & Coppola; Amy Gottfried, post-doc; Becky Matz, Ryan Sweeder, Ben Reynolds, Jeff Bartolin, Jess Hessler, graduate students; Ian Stewart, undergraduate


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**Thanks!**

**University of Michigan**
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- Provost’s Third Century Initiative
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- Carnegie Scholars
- Program on the Doctorate

**National Science Foundation**
- WIDER

**US Department of Education**
- GAANN