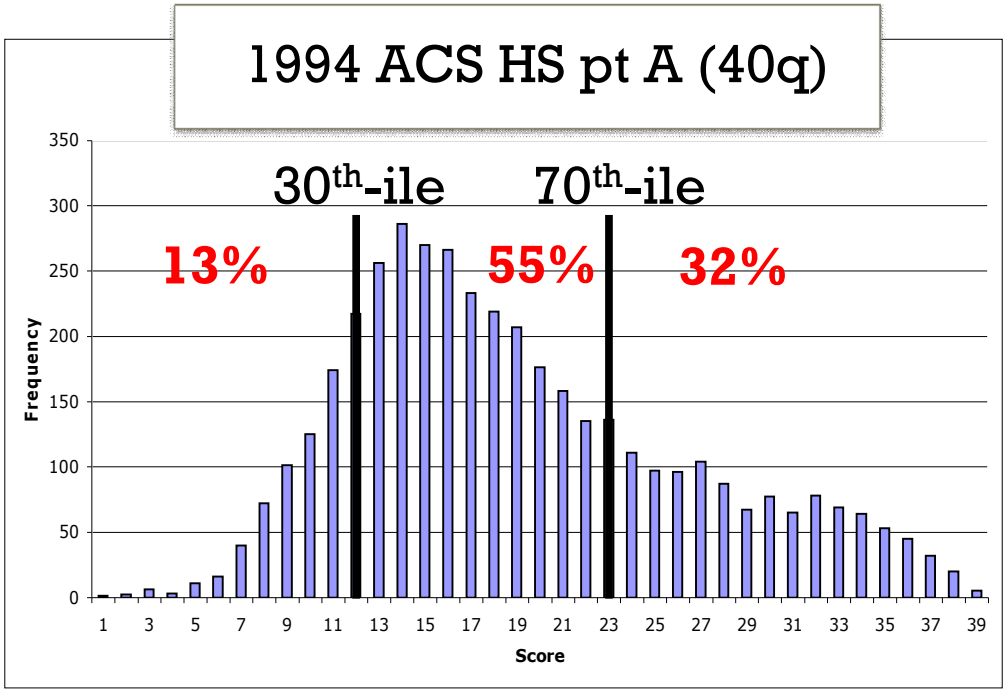
Real Work is better than Homework

LSA CHEMISTRY
UNIVERSITY OF MICHIGAN

CSIE | UM
Chemical Sciences at the Interface of Education
University of Michigan

Brian P Coppola
Arthur F Thurnau Professor of Chemistry
Associate Chair, Educational Development & Practice
Director, CSIE|UM

Context



SOURCE: University of Michigan – Office of the Registrar (2008)

1989-2015

Earns Gen Chem & Lab Credit

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

"Letter of Tested Exemption"

Logistics:
strong alignment in scope & sequence

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.

1989-2015

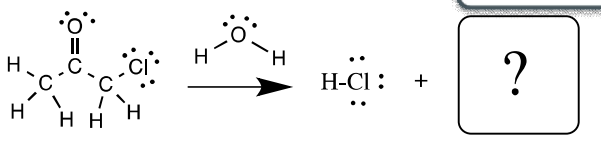
Earns Gen Chem & Lab Credit

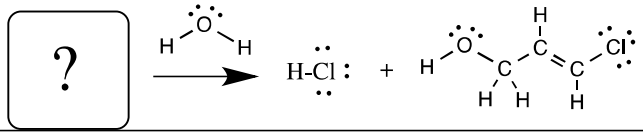
1400
35% AP
> 70th-ile
55% 1st Yr

"Letter of Tested Exemption"

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

Organic I + Intro Lab → Organic II + Org Lab





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

1989-2015

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

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

Earns Gen Chem & Lab Credit

"Letter of Tested Exemption"

Gen Prin
Gen Lab

~350

Organic I
Intro Lab

Organic II
Org Lab

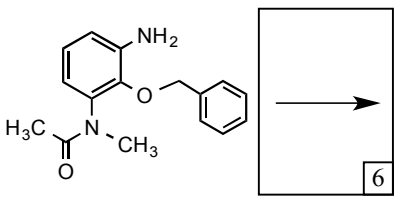
~250 majors per year in 6 degree programs

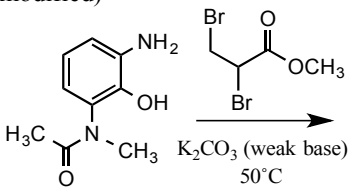
intro p-chem
(bio)inorg I
(bio)analytical
analyt lab
synth/char
phys method

The hidden curriculum

Complete the following reaction sequences as required.

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



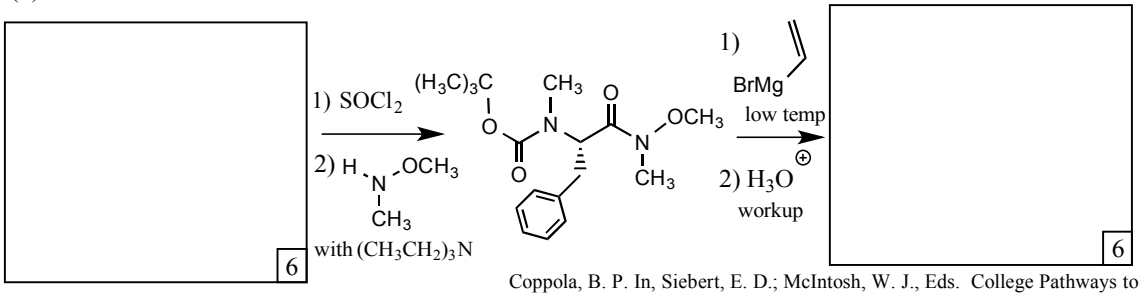


hint: the two substitution reactions take place in a specific and predictable order, to produce a single product

$C_{13}H_{16}N_2O_4$

8

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



Coppola, B. P. In, Siebert, E. D.; McIntosh, W. J., Eds. College Pathways to the Science Education Standards Arlington, VA: NSTA Press, 2001, 84-86.

Real Work Design Principles

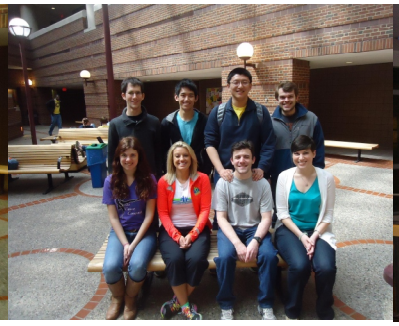
Coppola, B. P. "Do Real Work, Not Homework" In, Garcia-Martinez, J.; Serrano-Torregrosa, E., Eds. *Chemistry Education: Best Practices, Opportunities & Trends* Weinheim, Ger.: Wiley-VCH, 2015.

- 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



Varma-Nelson, P.; Coppola, B. P. "Team Learning." In, Pienta, N.; Cooper, M. M.; Greenbowe, T.; "Chemist's Guide to Effective Teaching" Saddle River, NJ: Pearson, 2005; 155-169.

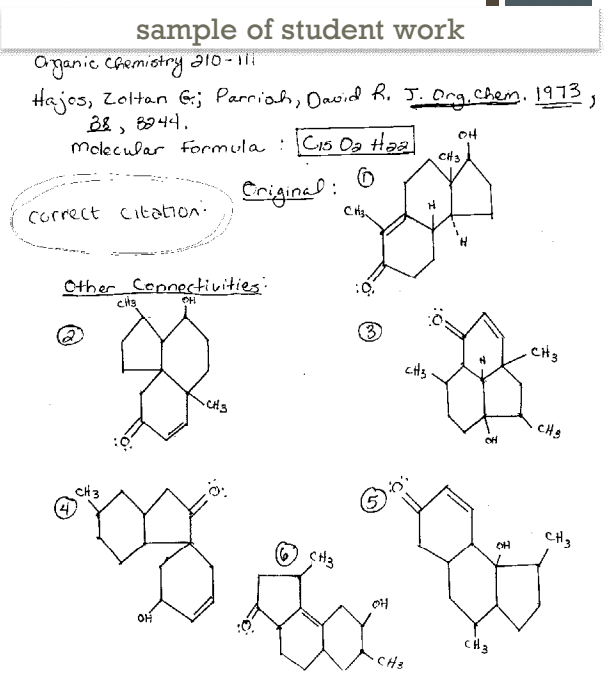
+ WEEK #1

Divergent Task:
find molecule $C_{13\text{-}15}H_yHet_{1\text{-}3}$
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

sample of student work



+ WEEK #3

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

JOC The Journal of Organic Chemistry
Featured Article
pubs.acs.org/joc

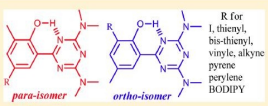
Synthetic Routes to Fluorescent Dyes Exhibiting Large Stokes Shifts

Sandra Rihn,[†] Pascal Retailleau,[‡] Antoinette De Nicola,[†] Gilles Ulrich,[†] and Raymond Ziessel[†,*]

[†]Laboratoire de Chimie Organique et Spectroscopies Avancées (LCOSA), UMR 7515 au CNRS, Université de Strasbourg, Ecole de Chimie, Polymères, Matériaux de Strasbourg (ECPM), 25 rue Becquerel, 67087 Strasbourg, Cedex 02 France
[‡]Laboratoire de Crystallochimie, ICSN-CNRS, Bât. 27-1 avenue de la Terrasse, 91198 Gif-sur-Yvette, Cedex, France

Supporting Information

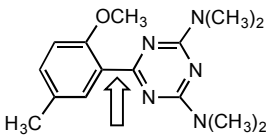
ABSTRACT: Derivatives of isomeric 2-(hydroxytolyl)-4,6-dimethylamino-1,3,5-triazines have been synthesized in high yields in a controlled manner using a multistep reaction sequence. Iodination of either 2-(1′-hydroxy-6′-methylphen-2′-yl)- or 2-(1′-hydroxy-4′-methylphen-2′-yl)-4,6-dimethylamino-1,3,5-triazine with ICl provides species differing in the positioning of the iodo group relative to the hydroxyl which readily undergo Suzuki, Sonogashira, and Heck reactions under Pd(0) catalysis.



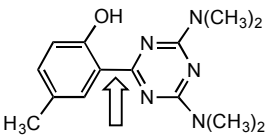
Thus, thienyl, bisthienyl, and 3,4-ethylenedioxythienyl groups have been directly grafted, while unsubstituted polycyclic aromatics such as pyrene and perylene have been linked via alkyne bridges, as have ethynyldifluoroborondipyrromethane (BODIPY) dyes prepared in situ. The presence of a hydrogen bond in the ground state involving the hydroxyl substituent has been established by proton NMR and several X-ray structure determinations. All of the new dyes with a simple substituent (phenyl, thienyl) exhibited a pronounced green fluorescence resulting from an intramolecular proton transfer in the excited state (ESIPT) which produces a large Stokes shift (>10 000 cm^{-1}). With other dyes, the fluorescence of the keto form responsible for the ESIPT process could be used as the input energy in efficient intramolecular energy transfer processes. Replacing perylene with pyrene allowed reversal of the direction of energy transfer from the polyaromatic module to the keto form.

The bond indicated by the arrow in compound **B** has a significantly higher barrier to rotation than the corresponding bond in compound **A**. Provide a drawing for compound **B** that best explains this large difference in the ability to rotate that bond.

compound **A**

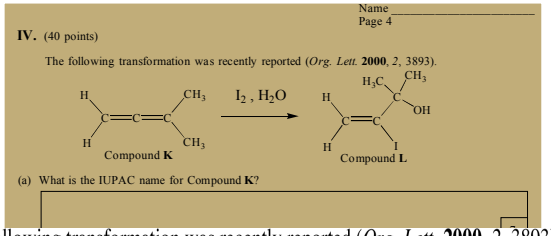


compound **B**



JOC 2012 77 5914–5921

+ Month-long projects: weekly milestones, presentations, reviews


Name _____
Page 4

IV. (40 points)

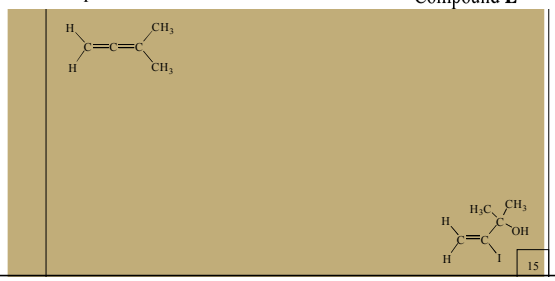
The following transformation was recently reported (*Org. Lett.* **2000**, *2*, 3893).

Compound **K** → (I_2, H_2O) → Compound **L**

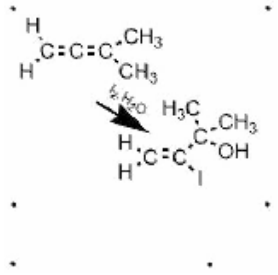
(a) What is the IUPAC name for Compound **K**?

The following transformation was recently reported (*Org. Lett.* **2000**, 2, 3893).

Compound **K** → (I_2, H_2O) → Compound **L**



Peer-to-Peer Explanations



Chemistry 215
Coursepack Podcasts

Natalie Reyes
Jock Schulz

Leader: Charles Frank Schuler
Term: Winter 2010

Chem 215 Coursepack
Problem (A)- Top of Page 82

Chem 215 SSG
Podcast:
Coursepack Page 83

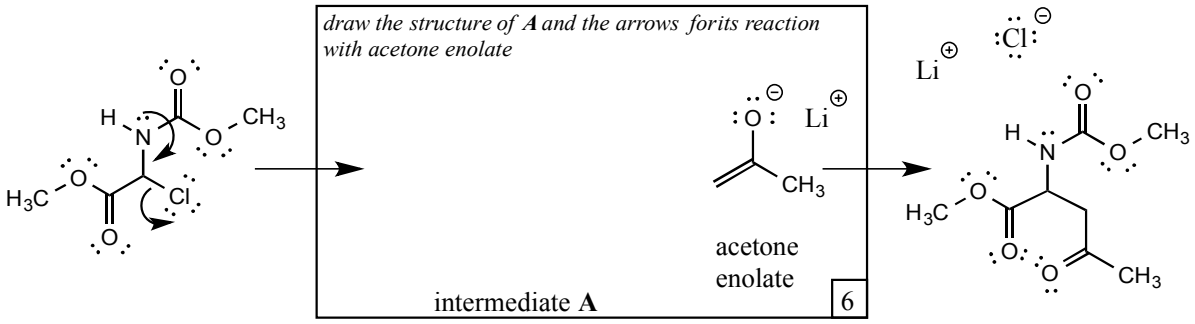
Fun With Hybridization!
Amanda Kupstas
Chelsea Russette
Josh Klinaszweski

+ 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.



+ Another example of student-generated instructional materials

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

sapling learning



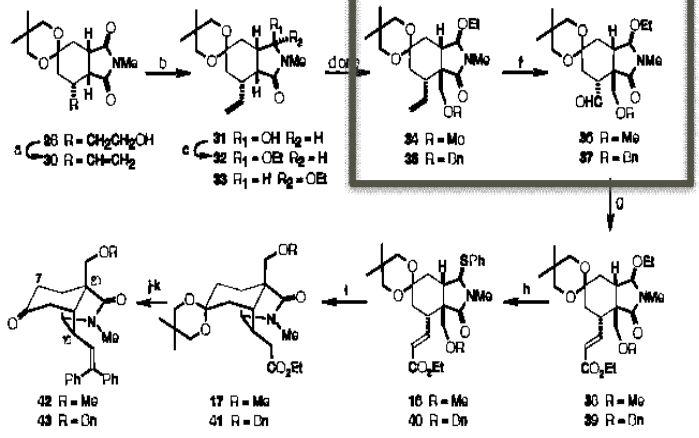
Goal: 100 great skill-based problems in each of 10 areas with a merciless tutor to bridge text/test gap?

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…
teams of 2-3 get a step



to teach
- 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?"

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

"Who has the same solid material as you do?"

"Who has the same…
- … liquid?
- … acid concentration?
- … numerical series?
- … dynasty artifact?
- … enzyme activity?
- … inhibitor concentration?

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.

+ Laboratory courses are a never-ending challenge.

RESEARCH-DRIVEN

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

Week 2: test some unreported substrates, write up results

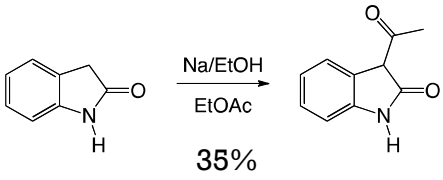
Week 3: exchange samples, are the results reproducible?

Next year: don't do the same thing

+ Laboratory courses are a never-ending challenge.

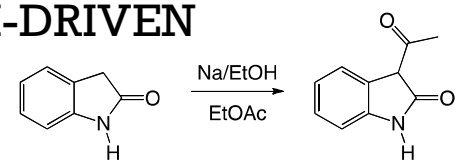
RESEARCH-DRIVEN

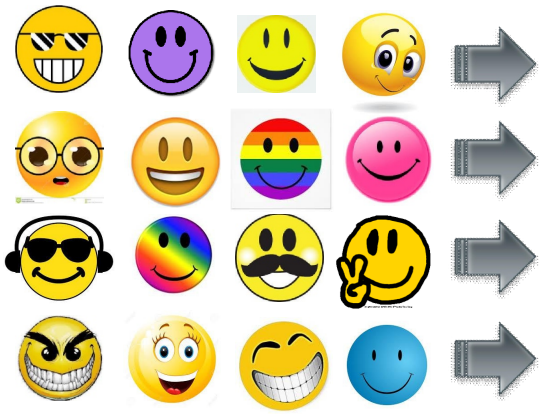
Is there a simple procedure being carried out that has not been optimized for yield?



+ Laboratory courses are a never-ending challenge.

RESEARCH-DRIVEN





temperature profile team

base concentration profile team

co-solvent profile team

stoichiometry profile team

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

The Interdisciplinary Challenge

Core Expertise | Core Expertise

Combined PhD in Chemistry & Education

MS in Postsecondary Education for future faculty PhDs

Stand-alone PhD in C[illegible]y E[illegible]n

Prof. Mark M Banaszak-Holl

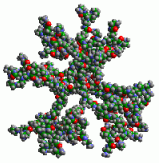
"research group" on drug transport based on gathering together & organizing the desired set of core expertise

Drug Transport Agents

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

Medical Nanotechnology

Macromolecular Science & Engineering



Physics

The Interdisciplinary Challenge

Core Expertise | Core Expertise

The historical development of understanding the alcohol dehydrogenase mechanism

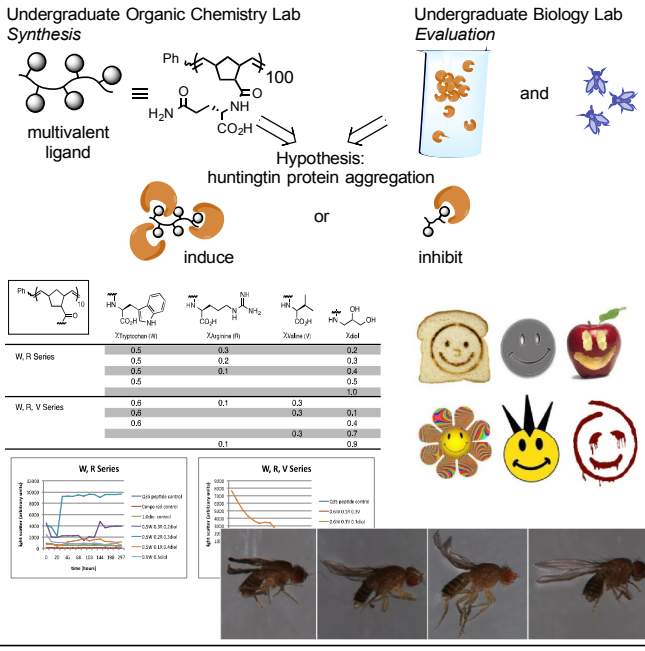
Week 1: Enzymatic transfer of hydrogen
(*J Biol Chem* **1953**, *202*, 687)

Week 2: Substituent & isotope effects in yeast ADH reaction
(*J Biol Chem* **1972**, *247*, 7977)

Week 3: X-ray structure of active site & mechanism for substrate specificity
(*J Biol Chem* **1997**, *272*, 18558)

Week 4: ADH activity & blood alcohol in women
(*NE J Med* **1990**, *332*, 95)

The Interdisciplinary Challenge



Boltax, A., Armanious, S. Pontrello, J.K., and Kosinski-Collins, M.S.. "Integration of the Biology and Organic Chemistry laboratories through a Huntington's disease research practicum." Association of Biology Laboratory Educators, Eugene, Oregon. June 17-20, 2014.

Bioch. & Mol. Bio. Education (in press)

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. "Advancing STEM teaching and learning with research teams" In Baldwin, R., Ed. "Improving the Climate for Undergraduate Teaching and Learning in STEM Fields" New Directions in Teaching and Learning (No. 117) San Francisco: Jossey-Bass; 2009; pp. 33-44.

Coppola, B. P. "The Most Beautiful Theories…" *Journal of Chemical Education* **2007**, 84, 1902-1911.

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.

Coppola, B. P.; Roush, W. R. "Broadening the Existing Intergenerational Structure of Scholarly Development in Chemistry" *Peer review* **2004** 6(3), 19-21.

sites.lsa.umich.edu/csie-um

CSIE | UM

Chemical Sciences at the Interface of Education | University of Michigan

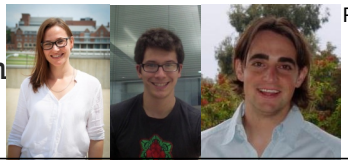
2014: hard line budget & a new Associate Chair position

Seminars
Workshops
Brown-Bags
Lit. Meetings

Prof. Peter J Alaimo
Seattle University
U-M BS (1994)

Prof. Sarah Goh
Williams College
U-M BS 1996

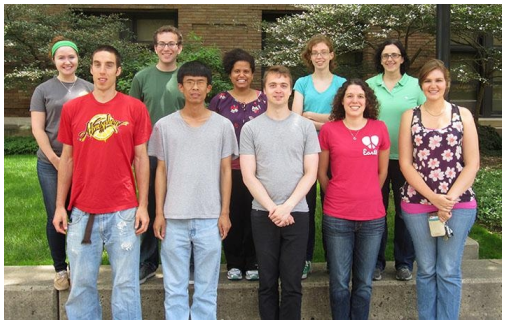
Prof. Suzanne Blum
UC-Irvine
U-M BS 2000



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

Moy, C. L.; Locke, J. R.; Coppola, B. P.; McNeil, A. J. "Improving Science Education and Understanding with Wikipedia" *Journal of Chemical Education* **2010**, *87*, 1159-1162.

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

Matz, R. L.; Krajcik, J.; Rothman, E.; Banaszak Holl, M. M. "Concurrent Enrollment in Lecture and Laboratory Enhances Student Performance and Retention" *Journal of Research in Science Teaching* **2012**, *49*, 659-689.

Gottfried, A. C.; Sweeder, R. D.; Bartolin, J. M.; Hessler, J. A.; Reynolds, B. P.; Stewart, I. C.; Coppola, B. P.; Banaszak Holl, M. M. "Design and Implementation of a Studio-based General Chemistry Course at the University of Michigan" *Journal of Chemical Education*

Thanks!

University of Michigan
- **Department of Chemistry**
- **LSA Honors Program**
- **Provost's Third Century Initiative**
- **Office of Instructional Technology**

Carnegie Foundation for the Advancement of Teaching
- **Carnegie Scholars**
- **Program on the Doctorate**

National Science Foundation
- **WIDER**

US Department of Education
- **GAANN**