

Undergraduate Research at the University of Michigan

Bringing in students as intellectual partners.

Brian P. Coppola

Arthur F. Thurnau Professor of Chemistry

Associate Chair for Curriculum & Faculty Affairs

Director: CSIE

(Chemical Sciences at the Interface of Education)



Undergraduate partnership - UM Chem

Research requires a substantially different skill set and set of interests than the study of material in courses. Early experiences in undergraduate research are critical for allowing students to evaluate their interest in a career of scientific intellectual exploration. It is a waste of the student's time and effort, and societies resources, to wait until the first to second year of graduate school to provide the experiences that allow the student to make this assessment.

Professor Mark M Banaszak Holl

The undergraduate students provide a wonderful catalyst for re-evaluating our scientific models. Their enthusiasm, and ignorance of the "right" answer, constantly challenges our preconceived notions and often lead to interesting breakthroughs in terms of both novel observations and the development of new scientific models.

Professor Mark E Meyerhoff

Undergraduate partnership - UM Chem

I often found undergraduate students to be brighter, more creative, and more productive than graduate students. Bear in mind that I am a dinosaur and a large part of my career has been before undergraduate research courses were ever offered. I hired undergraduate students as research assistants and many of them came up with extremely good ideas - - in computing, and in improvements of hardware and analyzing data. Much of the work resulted in very nice publications.

Professor Larry S Bartell

In Germany, I didn't do undergraduate research until a much later point in time...Only by participating in scientific investigation can students understand the nature of science and become scientists, that is, acquire problem-solving skills and learn critical thinking. I therefore encourage undergraduates to work in my laboratory; I even run my own foreign exchange program of German undergraduates visiting my lab for a period of 3-6 months, which 9 German students have done so far, in addition to the 18 UM students I have had (4 of whom had first-authored papers in the highest-ranking journals)... which also proves that we faculty can directly tap into the large intellectual resources of a young scientist's mind.

Professor Nils Walter

A typical large US Public Research University

University of Michigan (Ann Arbor)



- *established in 1817*
- *3200 acres (~1300 H)*
- *114,000 people*
 - *25,000 ugrad (5% nUS)*
 - *15,000 grad (20% nUS)*
- *425,000 living alum*
- *\$660M research budget*
- *200 ugrad programs of study*
- *19 Schools and Colleges*
 - *Literature, Science & the Arts*
 - *1200 faculty members*
 - *16,000 ugrad/2000 grad*
 - *20 institutes/programs*
 - *7 museums*
 - *25 departments*
 - *chemistry: 39 faculty*
 - *teach 3600 students/term*

Primer on US higher education:

- Carnegie Classification system & census (2000 report)
 - 3941 post-secondary degree-granting institutions
 - 43% grant 2-year degree
 - 15% grant 4-year degree
 - 15% grant 4-year + Masters
 - 7% grant 4-year + Masters + PhD
 - remainder: professional schools (MD, JD, DVM, DDS, Theology, Education)
 - 44% of undergraduate students enrolled
 - 6% of undergraduate students enrolled
 - 21% of undergraduate students enrolled
 - 26% of undergraduate students enrolled
 - Public Universities
 - enroll: 77% of undergraduate students
 - support: 30% taxpayer, 20% tuition, 50% gift/grant/research
 - 2-year public: average \$2100/yr tuition (non-residential)
 - 4-year public: \$5200 (+ \$6200) • private: \$20,000 (+ \$7500)
 - U Michigan: in-state \$9200 (+ \$7300); out-of-state: \$28,000 (+ \$7300)
 - increasingly private: in 1980, > 50% taxpayer; today, some are < 10%

Primer on US higher education:

- Historical link between research, Federal support, & public good
 - 1860s: Morrill Acts ('land grant' - state universities)
 - 1940s: Academic-Government partnership (NSF/NIH - HR development)
 - 1980s: Bayh-Dole Act (academic entrepreneurship)
- Undergraduates in higher education (2004)
 - 80% of all 18-24 year-olds are high school (HS) graduates
 - 67% recent high school graduates enrolled in higher education
 - 57% (1 in 20 of all HS students) take post-sec classes in HS
 - increasing participation: 1973: 30% 1991: 44%
- Faculty in higher education (2004)
 - 57% full time (1/1 non/tenure track) - 43% part-time
 - U Michigan: 2700 tenure/track; 700 non-tenure track

Undergraduate partnership - UM Chem

How can one understand the process of the creation of new knowledge without actually doing it? My undergraduate mentor guided me through the use of the scientific method to create new knowledge and also provided career advice that has helped me for the past 20 years. I would not be a chemistry professor in the absence of that undergraduate research experience. It is worth noting that I worked in the laboratory as a "work-study" student and received money as part of my financial aid package. If I had not been paid in this fashion for my undergraduate research experience, I could not have afforded to have taken the research position.

Professor William H Pearson

In the classroom, students sometimes feel that results appear from nowhere. At times, we are left asking "How?", "Why?", and "What if...?" Research allows me to apply what I've learned in the classroom to a laboratory setting.

Luke Janik, U Michigan

Some additional characteristics:

- Two worlds of research productivity
 - *Sciences & Engineering*
 - faculty productivity in research is linked to intergenerational groups (undergrad/grad/postdoc)
 - *Arts & Humanities*
 - “the more students I advise, the less work I get done”
- Professional/intellectual development infrastructure
 - 2-year schools *feed* 4-year schools *feed* PhD programs
 - student participation in research/civic participation
- “assumption” of student capability derived from (?):
 - tradition of pursuing practical/applied work in the public university
 - influence of experiential learning from *Technische Hochschule*
 - Laboratory instruction: Yale (1837) U Michigan (1854)

Undergraduate partnership - National

- Experiential Learning (Dewey, 1934: “*Do, do, do...*”)
 - Undergraduate research (UR) in the sciences & engineering
 - institutions & curricula established during industrial/technical growth
 - substantial demand for college-trained scientist/engineer labor force
 - pre-WW II: student technical assistants and “senior honors projects”
 - post-WW II: to get research funding, growth of summer UR at 4-year privates
 - Thurber: “Seeing is deceiving; it’s eating that’s believing.”
 - Franklin: “Easier to suppress a first desire than to satisfy those that follow.”
 - 1950s: Research Corporation (begins autocatalytic cycle)
 - 1960s: NSF Undergraduate Research Partnership; ACS PRF B
NSF/NIH Supplemental funding
 - 1980s: NSF Research Experience for Undergraduates; CUR
 - 2000s: NSF VIGRE; Undergraduate Research Centers
 - Service learning (internships, outreach, civic engagement, volunteerism, philanthropic activity, religious-based mission)
 - 1930s: Dewey/U Chicago sociologists - public accountability for higher education
 - 1960s: social activism
 - 1980/90s: community-based research & education in Arts/Humanities/Social Sci

Undergraduate partnership - UM Chem

If students spend four years only learning about p-orbitals, mechanisms and the like, they will come away with a skewed view of the world of science, one of old men and cookbook theories. Undergraduate research gives students the necessary perspective that what they are learning in the classroom can be applied to novel issues in science, provided they apply a little imagination to their work. Besides, who wants to learn how a bike works if riding it is not in the foreseeable future?

Pascale Leroueil, Graduate Student

Their presence enhances the research atmosphere in the lab due to their enthusiasm and questions. Their questions really force the graduate students, postdoctoral students and me to think hard, as the answers have to be on the fundamental level.

Professor Raoul Kopelman

As there an operational model?

- the “100-monkey effect”
- a somewhat “natural” evolution from the sciences and engineering has repeated itself in other areas
 - research is for the teacher/professor
 - *“Only social scientists can design, collect, and analyze survey data.”*
 - inexperienced students can watch, but not do
 - *“OK, you can ‘shadow’ me to see an experienced scholar in action.”*
 - after a while, students can do the drudge work
 - *“As long as you are standing there watching, make yourself useful.”*
 - student aptitude is a sliding scale
 - *“You’re only a sophomore? (Hmmm... you’re better than my senior.)”*
 - first order approximation is often adequate to doing good work
 - *“Say, that’s a rather interesting question... (Has that been done?).”*
 - learning & expertise is iterative and derived from practical knowledge
 - *“Sure, why don’t we try that?”*
- undergraduate research is itself an experiential learning activity for faculty members, and gets carried forward

Undergraduate partnership - U Michigan

■ UROP - Undergraduate Research Opportunity Program

- Campus-wide clearing house to match faculty and students
- Targeted at first- and second-year students
- Over 1000 student stipends/yr; 500 faculty mentors
- Supports normal faculty work & rewards:
 - Contribution to transforming and enhancing research productivity
 - Outcomes are usual: publications and leverage for additional resources
- Student rewards:
 - More proactive & engaged in their own education
 - Research competency, knowledge of field, enrolling in advanced degrees
- Institutional rewards:
 - Engagement in academic & social niches promotes retention

■ Arts of Citizenship Program

- Partnership with schools, museums, libraries, arts, public agencies
- Direct transformation of faculty work: ie, opening authentic venues for historical analysis in urban settings

■ Michigan in Washington (DC)

- One-term high energy residency in DC, courses and internship

■ Genre Evolution Project

- “research group” model in English: 100% enhancement to scholarly program

Undergraduate partnership - UM Chem

When I started college, I wanted to study chemistry because I naively felt like it offered black and white answers to really important questions about how the world works. After doing undergraduate research, I gained a huge appreciation for the challenges that went into getting those answers and even more importantly for the fact that with those answers often come more questions and shades of gray rather than black and white.

Professor Melanie S Sanford

Nearly all of the graduate students who have performed research in my laboratory over the past 26 years have relayed the same sentiment to me: that they would not have pursued this discipline were it not for the exciting opportunities in research that they experienced as undergraduates. Because I would not be where I am today because of the undergraduate research experience that I had nearly 30 years ago, I am committed to providing comparable opportunities for talented Michigan undergraduates.

Professor William R Roush

Undergraduate partnership - UM Chem

■ Demographics

- 1400 registered science majors in 10 science departments
- 190 chemistry & biochemistry
 - 60% end up enrolled for 3 terms or more
 - 95% end up enrolled for 2 terms
- UM Chemistry research: 39 faculty, 60 postdoc, 325 PhD students
 - Undergraduates enrolled in research during school year: 100-120
 - Undergraduates participating in summer research: 60-80

■ Funding

- Departmental: 30 summer fellowships (endowment/industrial gifts)
- Research supplements: 10-20 summer fellowships
- REU: 10 off-campus summer fellowships
- Intel: 5 additional REU for targeted populations
- International: graduate recruitment (2), research support (4), intern (1)

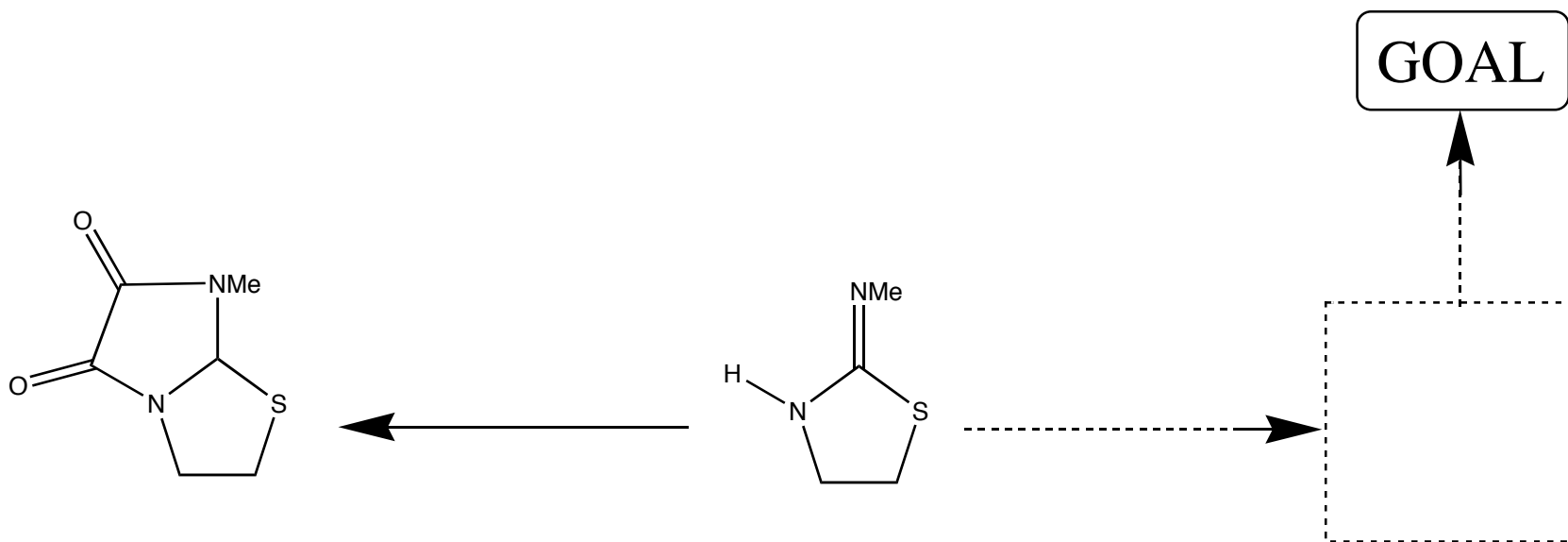
■ Publications (1994-2004)

- 2135 total : 214 with undergraduate coauthors
 - 69/214 with only undergraduate coauthor
 - 17/214 with summer REU students

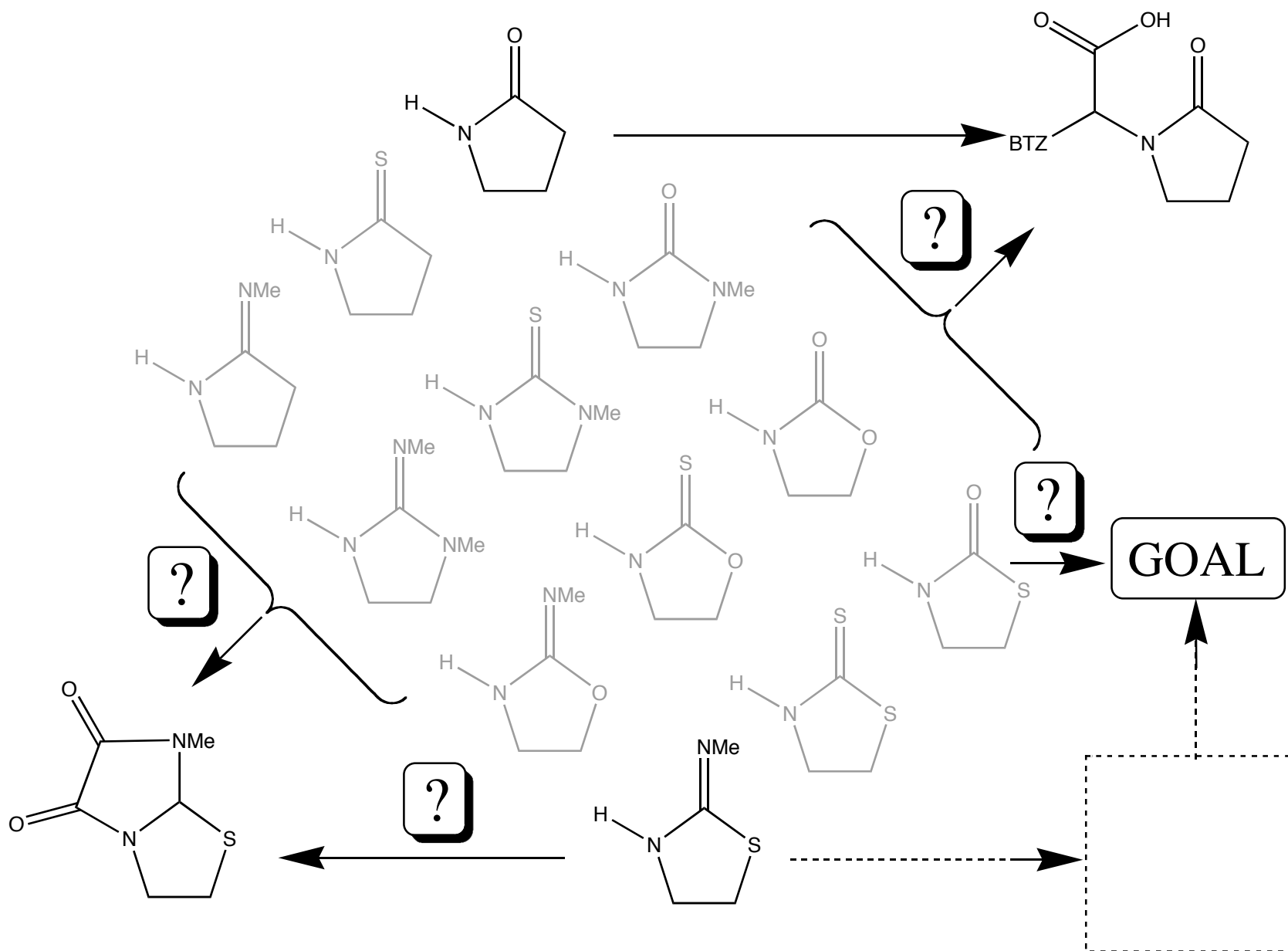
• Poster/talks

1054 w/ undergrads
307 w/ only UGs
160 include REUs

Undergraduate partnership - UM Chem



Undergraduate partnership - UM Chem



Undergraduate partnership - Summary

■ Benefits to Students

- Engagement
- Informed career choice
- Mentorship
- Membership in scientific community

■ Benefits to Faculty

- Nearly universal positive contribution to productivity
- Transform work into new areas
- Added mentoring training within groups (future faculty development)
- Give back to their own experience

■ Problems with Implementation

- Space, time, funding (in that order)

■ Surprises

- Impact on thinking about fundamental aspects of problems
- Ease with which non-US faculty adapt to “the assumption”

■ Evaluation

- Professional advancement via papers, posters, presentations

Undergraduate partnership - UM Chem

I learned how to design my own questions. Can I do this? Can I make these things bind together? Little did I know that my ideas would actually work! I learned how to read papers to glean other ideas out.

Kristen Schultz, Lawrence U

As a freshman to attend this program, I have learned a lot from it. In research experiment, I failed and made mistakes several times, but I have learned sometimes the mistake is just an opportunity to learn something new and failure maybe a blessing in disguise, and there's maybe hidden opportunity behind it. In living, I have learned that you must have independence to deal with the stuff in life, which reflect America Culture. I will bring this experience back to China to motivate me for further studying.

Jiacheng Guo, Shanghai Jiao Tung U

How do we carry out research? Who does it?

Faculty members who do research:

- get big ideas
- secure resources as needed
- implement new ideas

- alone

- with smart collaborators

- have many revelations

- Undergraduate
- Graduate
- Postdoctoral

Students who participate
in research as an education.

How do we carry out education? Who does it?

Faculty members who design instruction:

- get big ideas
- secure resources as needed
- implement new ideas

- alone

- with smart collaborators

- have many revelations

- Undergraduate
- Graduate
- Postdoctoral

Students who participate
in instruction as an education.

Chemical Sciences at the Interface of Education

GSI Training: (group: 3 graduate students)

Pipeline for Success: 5-week summer program for at-risk students (Chem/Biochem/Physics)

B. Coppola (group: 6 undergraduates)

Michigan Math & Science Scholars: 2-week summer program for gifted High School students

B. Coppola (group: 6 undergraduates)

General Principles: Active learning in large lecture

L. Lohr (group: 3 graduate students; 1 education faculty member and 1 student)

General Principles: “Studio 130” - integrated lab/lecture, smart classroom

M. Banaszak Holl (group: 15 people from all levels, plus from education)

Structure & Reactivity: Structured Study Groups - SI Honors Option

B. Coppola (group: 8 undergraduates)

Structure & Reactivity II: Project-oriented Honors section (lecture, lab, SSG)

B. Coppola (group: 1 postdoc & 4 undergraduates)

Intro Analytical Chemistry: Project based, fiber-optic/microcomputer-based

M. Morris & M. Meyerhoff (group: 1 post-doc and 5 graduate students)

Computational Chemistry Lab

R. Sension (group: 1 graduate student and 2 undergraduates)

Professional Writing/Speaking: senior capstone

E. Wimmers (Teaching Post-Doc) (group: 1 graduate student)

Graduate P-Org: Professional Development Projects

W. Pearson (group: 1 graduate student)

M. Sanford (group: 1 graduate student)

CSIE





CSIE

*Chemical Sciences
at the Interface of Education*

- **1991:** commitment to faculty line in discipline-centered teaching/learning
- **1994 - date:** undergraduate program
- **1998 - date:** graduate program
 - fellowships supports 8-12 chemistry PhD students per year
 - chemistry PhD students take 2 courses in education
 - external/internal speaker series
 - propose & carry out a teaching project in the department
 - on-campus collaboration
 - off-campus collaboration
 - presentations at professional meetings, & institutional seminars, workshops
 - publications
 - increased grad student ownership of PhD program
- **2002 - date:**
 - post-docs; thesis chapters; combined PhD degree (Chem & Educ)
- **2005-06?**
 - sustain & expand in department & in college

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