WHAT CAN WE LEARN ABOUT DOING CONTENT-BASED EDUCATIONAL RESEARCH ON TEACHING AND LEARNING FROM THE 30-YEAR HISTORY OF RESEARCH IN CHEMICAL EDUCATION?

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NCLT

- Goal:

  To increase the number of individuals trained in nanoscale science and engineering familiar with research in education.

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- Bodner, G. M. & Herron, J. D. (1984). Completing the Program With a Division of Chemical Education, *Journal of College Science Teaching*, *14*(3), 179-180.

Division of Chemical Education at Purdue

- Faculty
  - George Bodner
  - Mary Nakhleh
  - Bill Robinson
  - John Staver
  - Marcy Towns
  - Gabriela Weaver
- 37 graduate students working toward M.S. and/or Ph.D. degrees

Orgill, M-K. & Bodner, G. M. (2006). Theoretical Frameworks for Research in Chemistry/Science Education, Upper Saddle River: Prentice Hall

Constructivism and Social Constructivism; Symbolic Interactionism; Models and Modeling; Pedagogical Content Knowledge; Hermeneutics and the Meaning of Understanding; Phenomenology; Phenomenography; Action Research; Ethnography and Ethnomethodology; Situated Cognition; Telling the Whole Story via Narrative Analysis; Critical Theory; Feminism; and Afrocentric v. Eurocentric Views of Theoretical Frameworks

Ph.D. Graduates (n = 50 + 1)

Duke, Shippensburg, Purdue (2), SIU-Edwardsville (2), Clemson, Indiana University (PA), South Dakota State (3), Southern Arkansas, Grand Valley State (2), Cleveland State, UNLV, Lander, Ann Arundel, Akron, Northern Iowa (2), IUPUI, Northern Colorado, Nebraska-Omaha, Arizona State, Illinois State, UPR-Mayaguez, Penn State–Berks, SUNY College at Buffalo, Tennessee State, Indiana Academy, Middle Tennessee State, East Stroudsberg State, Delaware, Georgia, Kentucky, Mankato State, InterAmerican University (PR), Brebeuf Academy, Ferris State, Iowa State, North Carolina-Wilmington, Indiana University

The Effect of Pairing and Pacing on Learning Rate in ISCS Classrooms, Dorothy Gabel (1974)

- *Population*: 7th-grade students.
- *Curriculum*: Intermediate Science Curriculum Study (ISCS) written to allow students to learn at their own pace.
- *Assumption*: Materials lend themselves to mastery learning; written in a structured manner; gave students directions for the experiments they were to perform, and provided specific places in a workbook for them to record their observations and answer questions.
- *Structure*: Students worked at different rates; up to 10 chpts ahead of one another.

Observations:

- Some students appear to “nonpaced.”
- Students tend to procrastinate, particularly in large classes.
- Deadlines: Teacher has more control; may give the student impetus to work; but insufficient time to learn prerequisite skills.

Questions:

- What effect do time restrictions have on the rate of learning?
- Once deadlines are lifted, do students assume the same rates of learning as those who were self-paced?
- Does working with a partner increase learning rate?
- Do student pairs with different abilities learn at a faster rate?
- What is the effect of pacing/grouping on student attitude toward ISCS?
- What is the effect of pacing/grouping on achievement for students with different abilities?
- Does the ability of the student have an effect on the rate at which learning occurs?

Methodology:

- Set deadline versus allowing students as much time as needed while insisting they reach a given level of mastery before proceeding.

- Compare students working alone with those working in pairs.

Conclusions

- Self-pacing produced higher learning rates and retention scores than deadlines; particularly for low-ability children.
- Students with deadlines “cover” more concepts and are exposed to a wider range of skills than those who are self-paced and required to meet a criterion-level.
- The self-paced students learn the content of fewer chapters to a greater extent and are, therefore, learning more difficult concepts.
- Low-ability students who were self-paced learned at faster rates than students on deadlines.
- Working with a partner was beneficial, particularly for the low-ability students.
- Low-ability students who worked with a partner did better on retention tests.

Teacher's Beliefs About Science and Science Teaching: Narratives of Convictions, Actions and Constraints, Nancy Brickhouse, 1988

- *Hypothesis*: "In spite of considerable expenditure for research, educators have been ineffective in bringing about a change in the practice of teaching, perhaps because we have not considered the rationale teachers use in making instructional decisions."

- *Study*: Examine teachers' beliefs about science and science teaching, and how these beliefs shape their instruction.

- *Population*: Three teachers with diverse beliefs about science and varying years of classroom experience.

Cathcart:

Junior-high teacher; 25 years of experience; a strong logical positivist orientation to science. Science was taught as the truth, with theories being strictly right or wrong. His role was to transmit the truth to his students with lab activities that helped students discover the truth. His beliefs about science, science teaching, and his students created a consistent, self-reinforcing belief system to guide instructional decisions.

Lawson:

High-school physics teacher; 13 years of experience; viewed science as constructed facts and theories that serve to explain and predict observations. Theories were tools to solve problems rather than truth. Memorizing theories, but not being able to apply them to novel problems was not highly valued. Theories were not accepted solely on the authority of the teacher, but were examined in light of observations. Once again, the beliefs of the teacher were remarkably consistent and self-reinforcing.

McGee:

Junior-high teacher in his 2nd year; beliefs about science were a mix of logical positivism and newer philosophies; had considerable difficulty implementing instruction consistent with his stated beliefs. Reasons: (1) Some of his beliefs contradicted each other, (2) he was still learning the science content while he taught it, and (3) there were institutional barriers to implementing his desired instruction.

The Beginning Science Teacher: Narratives of Convictions and Constraints, *Journal of Research in Science Teaching*, **1992**, *29*, 471-485.

- This study illustrates how beginning teachers struggle to reconcile: (1) conflicting beliefs about what is desirable, and (2) conflicts between what they want to achieve and what is possible within the constraints of their preparation and the institutions in which they work.
- McGee struggled to reconcile his view of science as a creative endeavor with his belief that students need to be provide with a high degree of structure in order to learn within the context of formal schooling.
- He also had difficulty resolving the conflict between the informal, "messing about" type of science learning that he believed was desirable with the personal and institutional constraints he faced in the classroom.

Research in Chemical Education Symposia

- 187th American Chemical Society Meeting, St. Louis, MO, April, 1984

  6 papers, half-day

- 8th Biennial Conference on Chemical Education, Storrs, CT, August, 1984

  Full day symposium

- 18th BCCE, Iowa State, August, 2004

  Six half-day sessions, 35 papers, 20 institutions, four foreign countries, plus papers on chemical education research in 10 other symposia

Journals

Journal of Research in Science Teaching (NARST)

Science Education (Wiley)

Journal of Chemical Education (ChemEd Division)

Journal of College Science Teaching (NSTA)

Science & Education (IHPS&T Group)

The Chemical Educator (Kluwer)

University Chemistry Education (RSC)

Chemical Education: Research and Practice (RSC)

Biochemistry and Molecular Biology Education (ASBMB)

Chemical Engineering Education

Journal of Engineering Education (ASEE)

IEEE Transactions on Professional Communication (IEEE)

Interdisciplinary Journal of Problem-Based Learning (Purdue)

David Gardner 2002, (Lander University)

Original Guiding Research Question:

How do students learn quantum mechanics?

Original Answer:

Not very well.

Revised Guiding Research Questions:

- What are the experiences of students learning quantum mechanics?
- What conceptual difficulties do students have with quantum mechanics?
- How do students approach learning quantum mechanics?

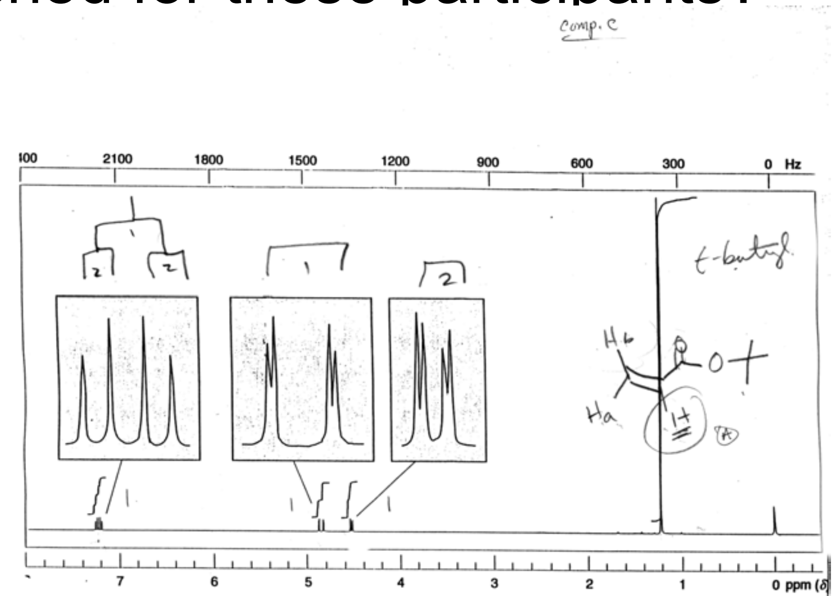
David Cartrette, 2003 (South Dakota State)

- *Research Questions*:

  How do organic chemistry graduate students and faculty solve combined spectral problems?

  What problem solving characteristics differentiate successful and unsuccessful problem solvers?

  Can a continuum of problem solving ability be established for these participants?



Patterns in Confidence/Performance:

More successful: >80% (n = 8)

Confidence: 7.3 Performance: 8.5

Less successful: <70% (n = 5)

Confidence: 7.2 Performance: 6.0

Patterns in Approach of Successful Problem Solvers:

- Took consistent, appropriate approaches to solving problems of this type.
- Made use of more information, including coupling constants that must be deduced from analysis of the spectrum.
- Drew out fragments of molecules as they were deduced.
- Checked their solutions against the spectral data.

Provi Mayo, 2004 (South Dakota State)

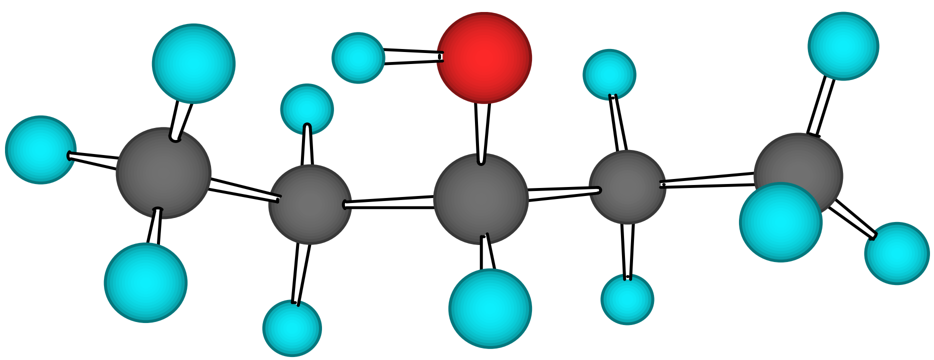
Research Questions:

- How do blind students translate abstract chemistry ideas in their textbooks into a two-dimensional image or drawing?
- What symbols do they use to represent the translated ideas?
- How do blind students decide to use certain symbols to represent the abstract material given to them in the text?
- What discrepancies arise when blind students compare their perceptions of abstract concepts from the text and their haptic perception of raised-line drawings of those figures? How do they reconcile these differences?

Mike Briggs, 2004 (Indiana University of Pennsylvania)

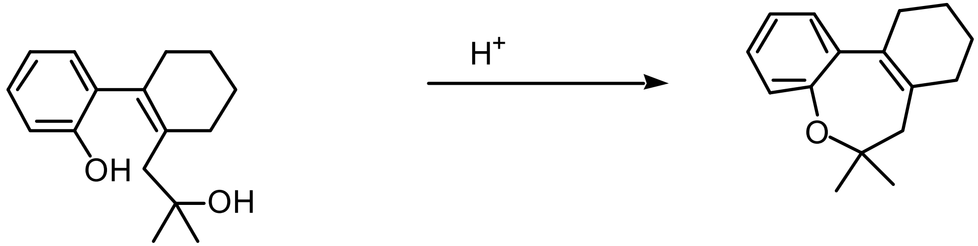
Goal: To understand the unconscious structure and processes that account for an individual's ability to mentally rotate molecules and to build a model of these processes.

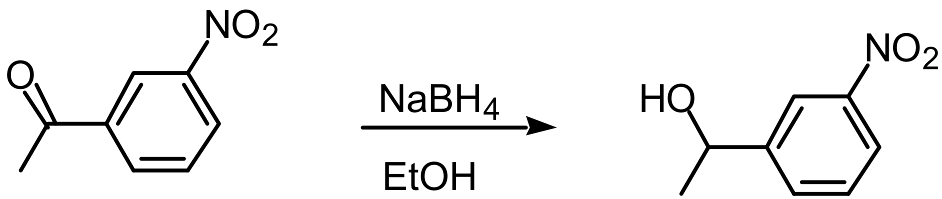
If you rotate the following molecule until the hydrogen atom on C3 is behind the third carbon atom, what would the molecule look like in three dimensions?

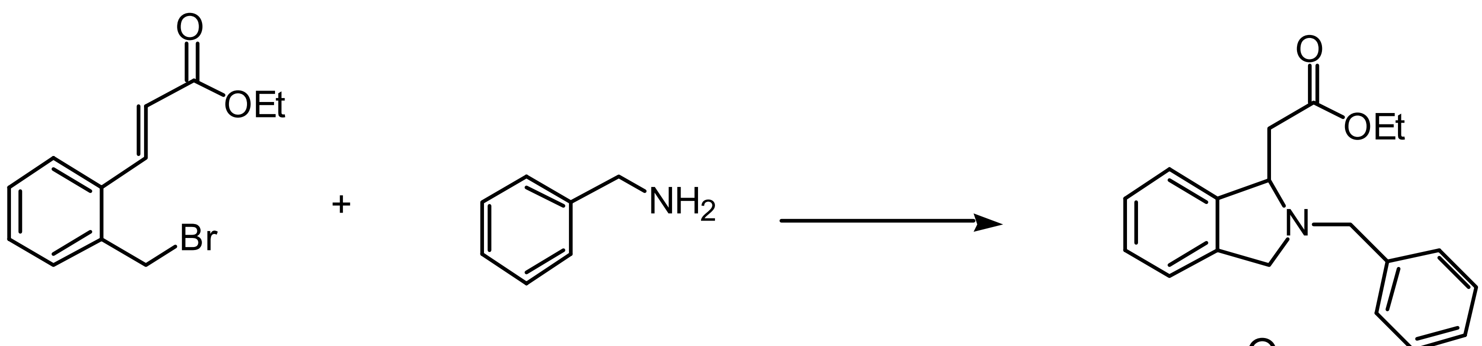


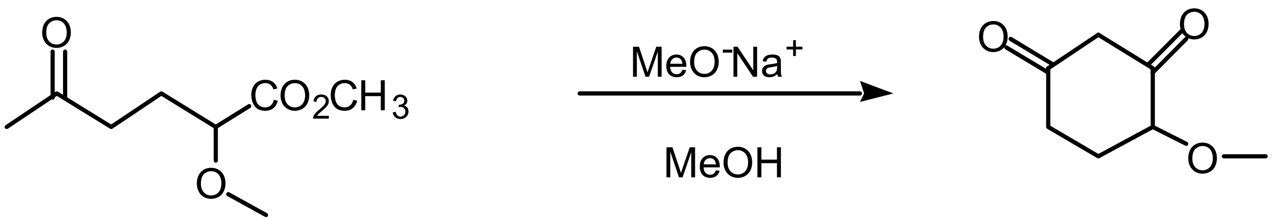
Rob Ferguson, 2004 (Cleveland State)

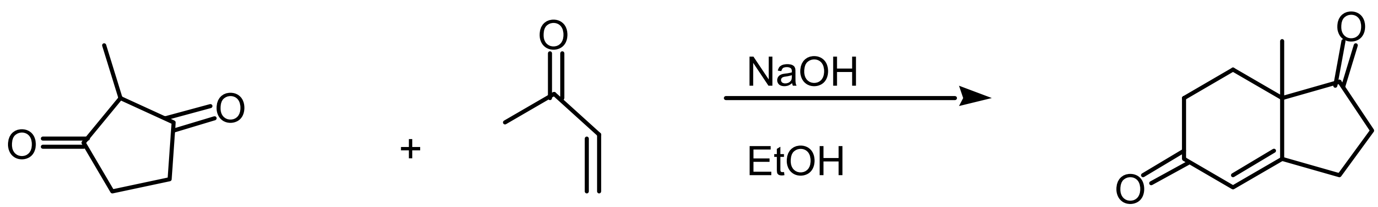
- How do students make sense of the arrow-pushing formalism?
  - What are the barriers to sense-making?
  - What are the misconceptions?
  - What do the students apply?
  - Is something missing that would facilitate understanding?
- What are the process that students use to complete an arrow-pushing mechanism?
  - What are the differences, if any?
- What differences exist in the understanding of arrow-pushing mechanism at the different academic levels (undergraduate student, graduate student, professor)?


OH
OH
H+
O


O
NO2
NaBH4
EtOH
HO
NO2


O
OEt
Br
+
NH2
O
OEt
N


O
CO2CH3
O
MeO-Na+
MeOH
O
O
O


O
O
+
O
NaOH
EtOH
O
O

Gautam Bhatacharyya, 2004 (Clemson)

- *Pilot study assumptions:*

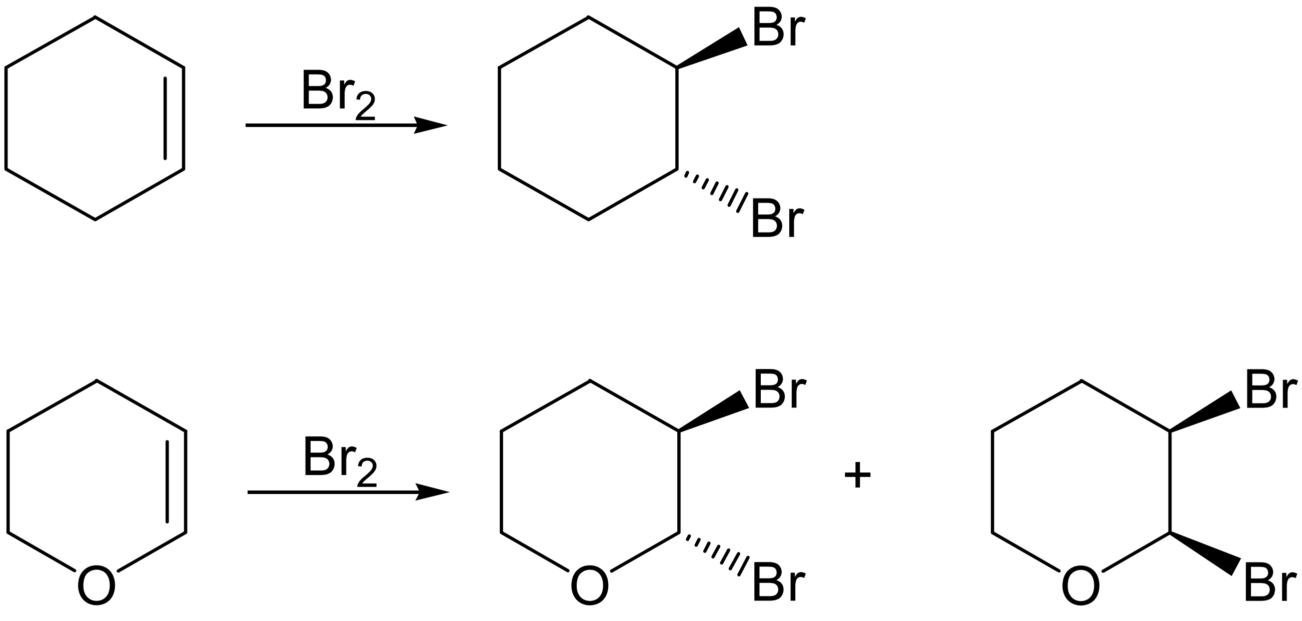
  Mechanisms play a key role in predicting the products of organic reactions.

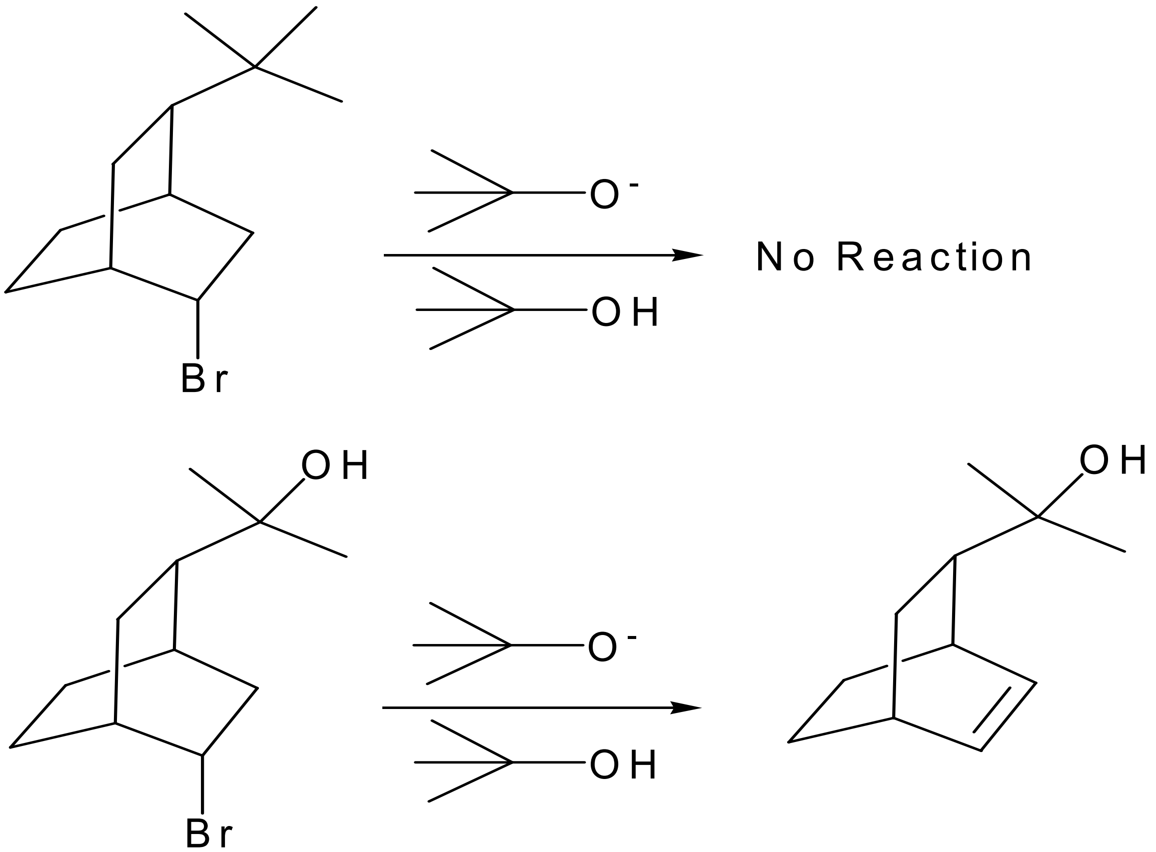
  These mechanisms are communicated using curved-arrow, electron-pushing drawings.

  Practicing organic chemists use this formalism in the ever-changing environment of new molecules, outside of the traditional contexts in which they are taught.

- *Goal*:

  Study how graduate students solve mechanism problems that were far removed from the simple systems in which mechanisms are presented.


Br2
Br
Br
Br2
O
Br
Br
+
O
Br
Br


O -
OH
No Reaction
Br
OH
O -
OH
Br
OH

Conclusions

- The curved arrows held no physical meaning.
- They weren't symbols (Bodner & Domin, 2000) because they didn't symbolize anything in the students' minds.
- The students didn't understand the function of this formalism as it is used by practicing chemists.
- Mechanisms were just blueprints for reactions they had to memorize.
- Mechanisms were not connected to activities in the lab.
- The most common justification for any step in the problem-solving process was: "It gets me to the product.“

Ph.D. Dissertation:

- **Assumptions:**

  Knowledge is constructed in the mind of the learner.

  This construction occurs in a social environment.

- **Observations:**

  Graduate students taking graduate-level courses exhibit the behavior of students, not practicing chemists.

  With time, they undergo the process of acculturation to the community of practicing organic chemists.

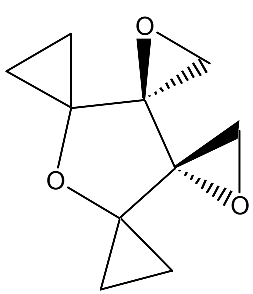
Research Questions:

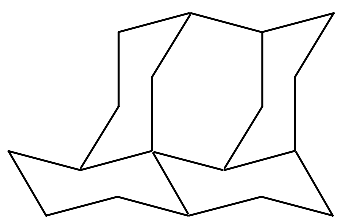
- What processes do graduate students in organic chemistry use to solve organic synthesis problems?
- How do graduate students in organic chemistry learn to solve organic synthesis problems?
- How does acculturation among graduate students affect the problem-solving process?
- Why do students have difficulty learning organic chemistry?

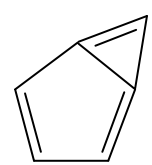
First-year Participants

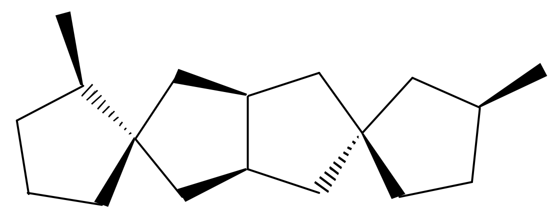
- First-year students enrolled in a graduate-level advanced organic synthesis course.

  HW contained a short synthesis task; three exams that covered named reactions (30%) and questions based on papers from JACS or JOC (70%); and a term-long total synthesis.



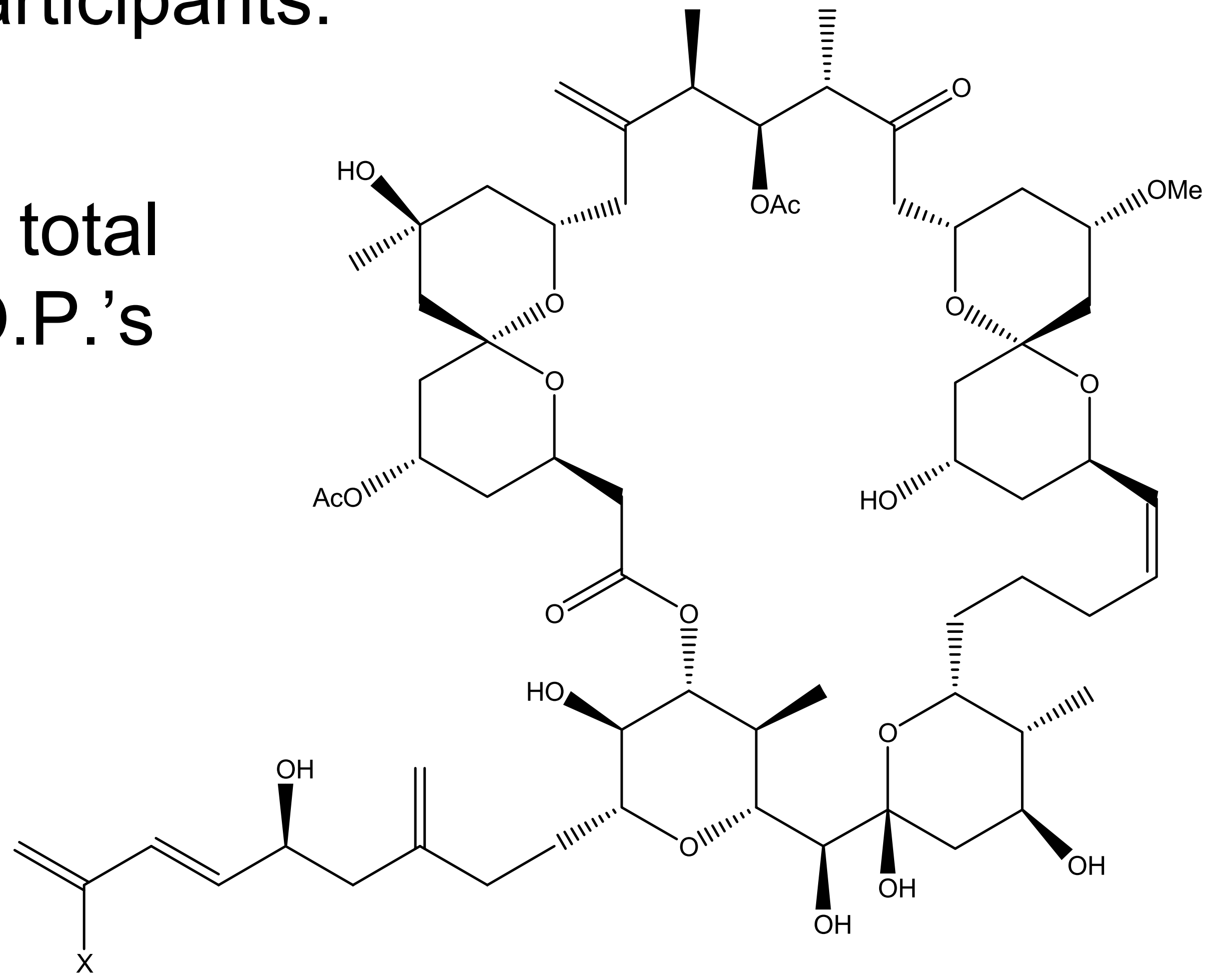






Third-Year Participants:

- Working on total synthesis O.P.'s



X = Cl Spongistatin 1
X = H Spongistatin 2

Hypotheses:

- Chemical education research is like research in any other domain of chemistry. It is the process, not the product that is important.

- Implementing chemical education research programs is similar to calling for inquiry-based instruction in the K-12 classroom — it focuses attention on the process by which students learn, thereby making the researcher a better teacher.

Peter Fensham: Science for Everyone

Action Research: Every teacher a researcher

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Questions and Answers