

Been there. Done that.

Time to Rethink Teaching and Curricular Design



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Importance of chemistry

...from a popular perspective...



Top Ten Scientific Discoveries

WIRED

12Dec12

- Higgs boson discovered
- *Curiosity* lands on Mars
- Rise of rare variants [disease genomics]
- Genome sequencing for fetuses
- Quantum teleportation distance record broken [particles]
- Life's new chemical code [synthetic DNA polymer]
- SpaceX launches to space station [first private company]
- Earth's exoplanet twin
- Scientist reach Lake Vostok [frozen under Antarctica]
- Ending invasive chimp research

WIRED

13Dec18

- Humankind goes interstellar [36 y.o. Voyager in deep space]
- Genome editing
- Billions and billions of Earths
- Global warming: cause for the pause [deep oceans, equatorial Pacific]
- See-through brain [treatments to make transparent by fluorescence]
- Intergalactic neutrinos [detector]
- New North American mammal [olinquito]
- Pesticide controversy [neonicotinoids]
- Making organs from stem cells
- Implantable electronics [biodegradable]

What have we been doing in General Chemistry?

...curricula and content...



Introductory science taught in lectures

Persistent Questions

- Stress theory, facts, or both?
- Do we teach too much?
- “Electronic” concepts?
- Early in the course?

Decisions about content...

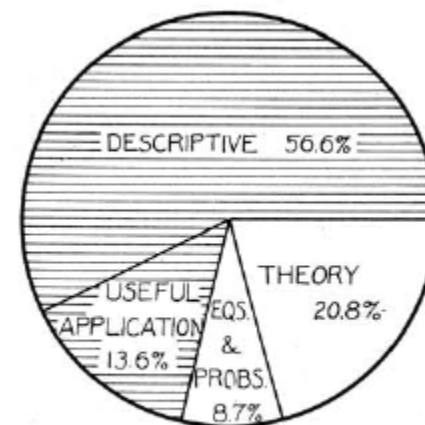
J. Chem. Educ. 1924, 1, 5-13.

WHAT WE TEACH OUR FRESHMEN IN CHEMISTRY

JACOB CORNOG AND J. C. COLBERT, CHEMISTRY DEPARTMENT,
UNIVERSITY OF IOWA, IOWA CITY, IOWA

TABLE V. DATA FROM QUESTIONNAIRES FROM 27 COLLEGES AND UNIVERSITIES

Institution	No. Stdnts	Text Used	Stress Theory, Facts, Both?	Do we teach too much?	Use Electron Concepts?	Early in Course?
1. Ames (Iowa)	1200	Mc P&H	Theory	Yes	Yes	Yes
2. Arkansas	250	Mc P&H	Both	Yes	Yes	No
3. California	800	Hild	Theory	Yes	Yes	Yes
4. Chicago	150	Smith	Theory	..	Yes	Yes
	150	McC & T	Both	..	Yes	Yes
5. Columbia	400	Smith	Facts	Yes	Yes	Yes
6. Cornell	1100	Mc P&H	Facts	Yes	Yes	No
7. Harvard	400	Smith	Theory	No	Yes	After 3 mos.
		Mc P&H				
8. Illinois	1300	Noyes	Both	Yes	No	..
9. Iowa U	600	Smith	Both	Yes	No	..
20. Purdue	1000	Holmes	Both	No	No	..
21. Stanford	300	Holmes	Theory	Yes	Yes	No
Totals	18100		Theory 13 Fact 2 Both 3	Yes 18 No 7	Yes 20 No 7	Yes 12 No 10



CONTENT OF COLLEGE TEXTS

The role of textbooks

...a short historical perspective...



Some Perspectives

Smith's College Chemistry by James Kendall

- © 1905, 1906, 1908, 1916, 1923, 1929
- 759 pages, 49 chapters

Chemical view of matter
Chemical Change
Combining Proportions
Atomic Theory
Symbols
Oxygen
Gases
Hydrogen
Valence
Water
Molecular Weights...

Chemistry by Michell Sienko and Robert Plane

- Self-published in 1957 (\$4)
- JCE reviews: 1961, 1964, 1980
- 2nd ed: 623 pages (\$7.50)
- Followed basic principles

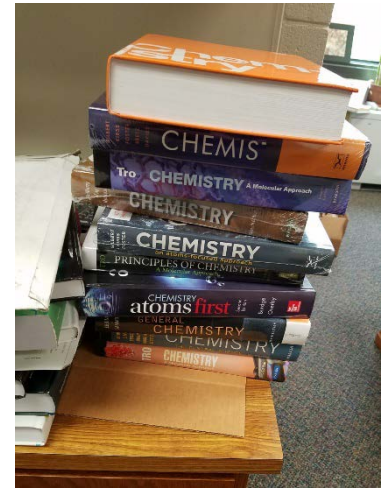
Nothing that is not completely correct
Do not oversimplify; instead omit
Help students understand
Nothing not given in lectures
Lots of problems
Distinguish fact from theory
Theory before descriptive chemistry



Publishers Dictate Curriculum?

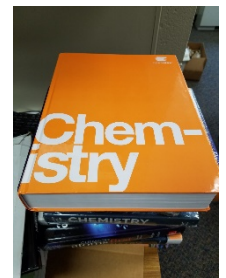
Commercial enterprise

- mid-1980s to mid-1990s: 25+ publishers
- Current: 5+ publishers
- Costly / profitable
 - From \$450 for text, study guide, solutions manual, CD
 - To \$120 e-book
 - To OpenStax (free??)



More is better

- choices of chapters became need to cover the material



“Saugage” model

What can we do?

...and how to decide...



Making decisions based on evidence

National Academy of Science studies / papers

- DBER Report (2012)
 - Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering
 - <http://www.nap.edu/catalog/13362/discipline-based-education-research-understanding-and-improving-learning-in-undergraduate>
- DBER into practice (2015)
 - Reaching Students: What Research Says About Effective Instruction in Undergraduate Science and Engineering
 - <http://www.nap.edu/catalog/18687/reaching-students-what-research-says-about-effective-instruction-in-undergraduate>



Evidence about active learning

PNAS Active Learning Metastudy

- 225 studies
 - All class sizes show benefit; greatest for <50 students
 - Significant for all of STEM
 - Effect sizes
 - performance on exams, concepts inventories: active vs lecture avg = +0.47 SD
 - odds ratio for failing on traditional = 1.95
- “Active” class scored +6% on exams: half letter grade;
 - Traditional class 1.5x chance of failure (i.e., DFW)

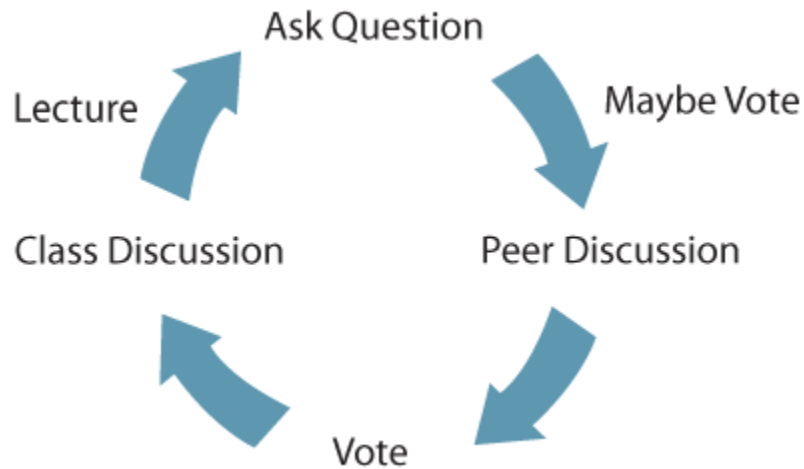
Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23), 8410-8415.



Peer Instruction

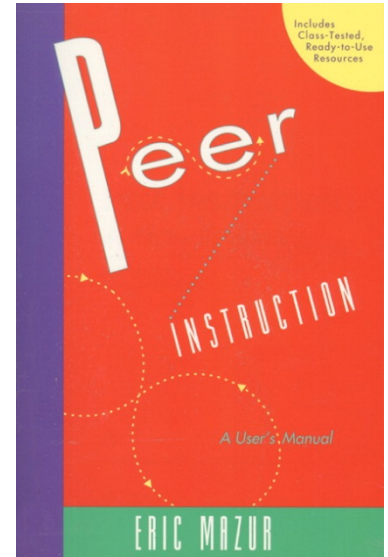
Peer Instruction Model

- Eric Mazur (Harvard, Physics)
- since 1991



- Basis for current use of “clickers” in classroom

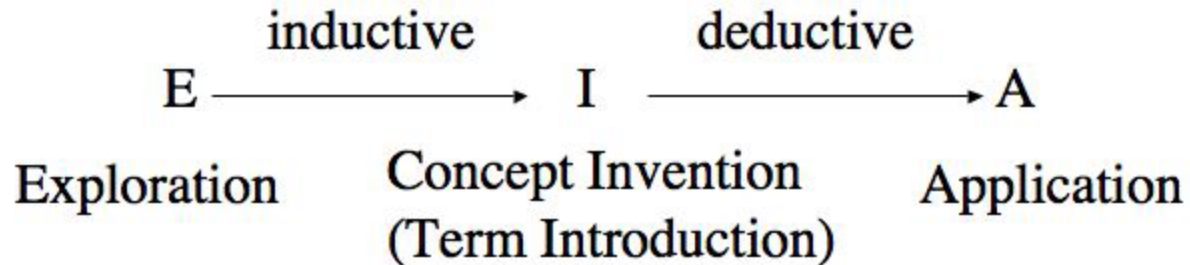
Crouch, C.H.; Mazur, E.; “Peer Instruction: Ten years of experience and results,” *Am. J. Phys.*, **2001**, 69, 970; doi: 10.1119/1.1374249





Process Oriented Guided Inquiry Learning

- Franklin & Marshall → NSF grants → nat'l dissemination → www.pogil.org
- Learning cycle



- Groups with roles [manager, reporter, observer]
- Activities / worksheets / questions



PLTL

Peer Led Team Learning

- Gosser, Varma-Nelson, Kampmeier → NSF grants → nat'l dissemination
- cooperative learning groups [some roots in Supplemental Instruction]
- team leader is critical [role & training]
- group activities / questions



SCALE-UP (or TILE) Classrooms

Student Centered Active Learning Environment w/ Upsidedown Pedagogies

- Bob Beichner (NCSU, Physics); ~40 years
- groups: 3 @ 3 = 9
- activities
- technology





Curricular alternatives

Commercial

- ACS sponsored General Chemistry text
- Atoms first (fundamentals of matter and atoms)

Esterling & Bartels, *J. Chem. Educ.* **2013**, *90* (11), 1433-6

CLUE (“Chemistry, Life, the Universe and Everything”)

- Melanie Cooper (Michigan St) and Mike Klymkovsky (Colorado)
- structure & properties, bonding & interactions, energy, change
- addresses large number of bio majors

Cooper & Klymkovsky: <http://clue.chemistry.msu.edu/>

“Chemical Thinking”

- Vicente Talanquer (Arizona)
- way of thinking rather than static body of knowledge

Sevian & Talanquer *Chem. Educ. Res. Prac.*, **2014** *15* (1), 10-23.