Been there. Done that.
Time to Rethink Teaching and Curricular Design

Norbert J. Pienta
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Importance of chemistry

…from a popular perspective…
Top Ten Scientific Discoveries

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

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?
WHAT WE TEACH OUR FRESHMEN IN CHEMISTRY

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UNIVERSITY OF IOWA, IOWA CITY, IOWA

TABLE V. DATA FROM QUESTIONNAIRES FROM 27 COLLEGES AND UNIVERSITIES

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Theory: 13 Yes 18 Yes 20 Yes 12
Fact: 2 No 7 No 7 No 10
Both: 3

CONTENT OF COLLEGE TEXTS

- DESCRIPTIVE: 56.6%
- USEFUL APPLICATION: 13.6%
- THEORY: 20.8%
- EQS & PROBS: 8.7%
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

*Chemistry* by Michell Sienko and Robert Plane
- Self-published in 1957 ($4)
- 2nd ed: 623 pages ($7.50)
- Followed basic principles

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

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

“Sausage” 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)

Peer Instruction

Peer Instruction Model

• Eric Mazur (Harvard, Physics)
• since 1991

• Basis for current use of “clickers” in classroom

Process Oriented Guided Inquiry Learning

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

\[
\begin{align*}
E & \rightarrow \text{inductive} \rightarrow I \rightarrow \text{deductive} \rightarrow A \\
\text{Exploration} & \rightarrow \text{Concept Invention (Term Introduction)} \rightarrow \text{Application}
\end{align*}
\]

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

[https://pogil.org/]
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)

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

“Chemical Thinking”

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

References:

- Cooper & Klymkovsky: [http://clue.chemistry.msu.edu/](http://clue.chemistry.msu.edu/)