Using the 2008 ACS Guidelines to Promote Excellence, Rigor, and Innovation in Undergraduate Chemistry Programs

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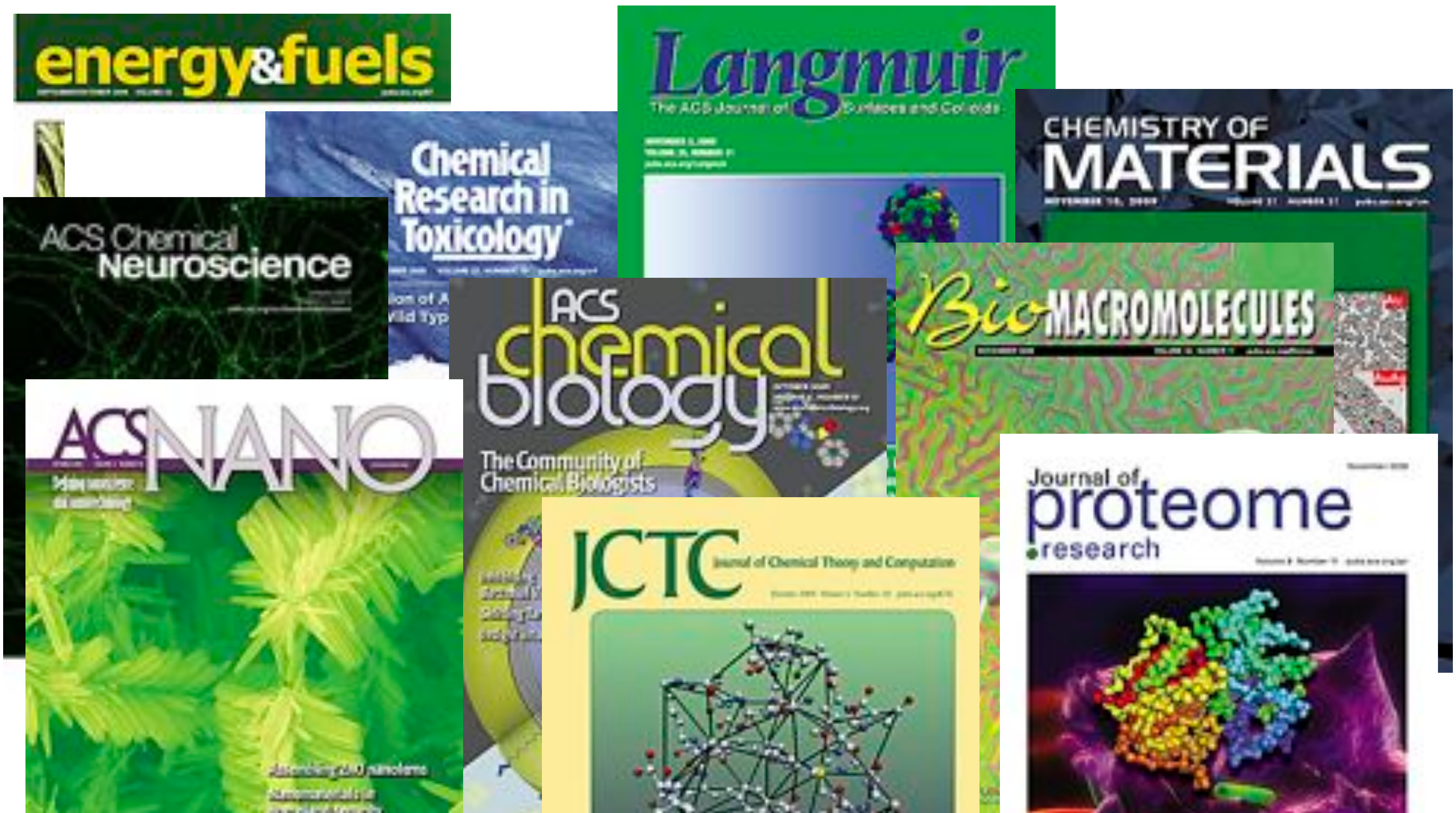
Overview

- Changes have occurred in the chemistry profession, in chemistry education, and in chemistry students
- Chemistry departments must change to remain relevant and serve their students well
- The 2008 ACS Guidelines for Undergraduate Chemistry Programs are a vehicle for leading departmental change that promote excellence, rigor, and innovation

Chemistry Profession is Changing

Chemistry increasingly interacts with other disciplines to create new scientific fields



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Chemistry uses advanced technology and addresses more complex problems

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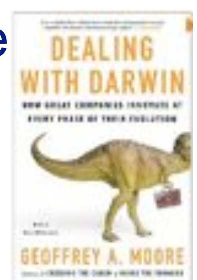
Chemistry uses advanced technology and addresses more complex problems

Chemistry has become a global concern

"In an environment of ***globalization***, deregulation, and commoditization, ***innovation*** creates differentiation which is paramount. Differentiation in turn creates competitive advantage."

"Arguing against ***globalization*** is like arguing against the laws of gravity."

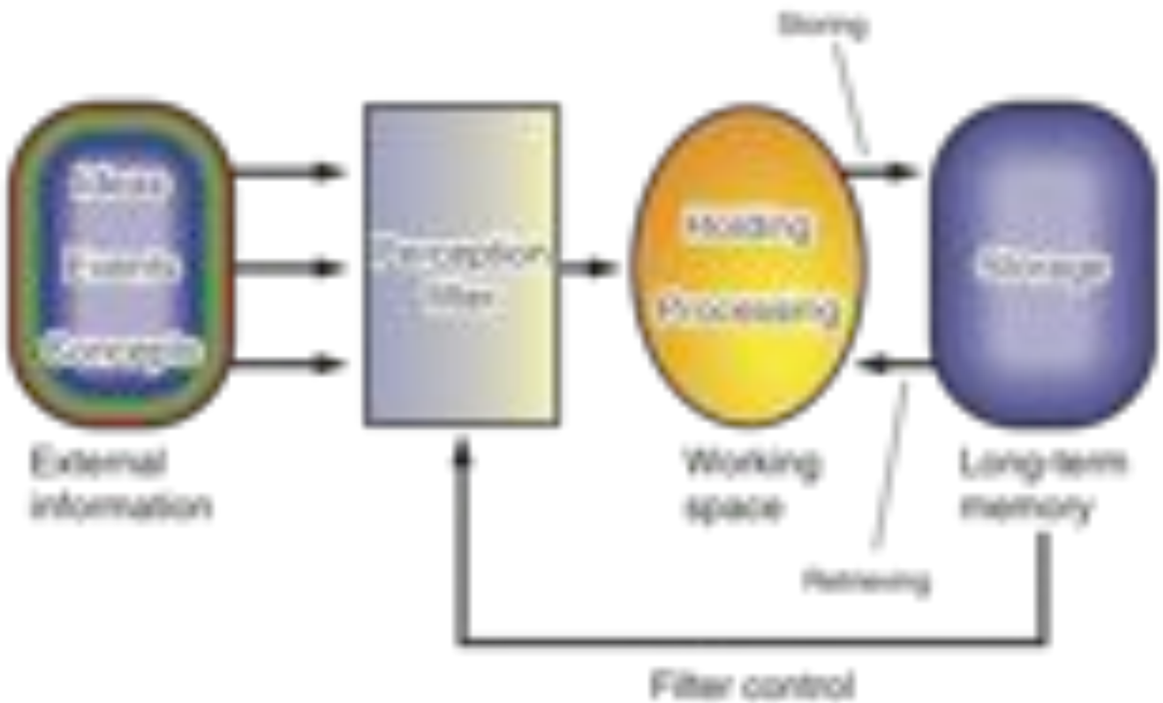
– Kofi Annan,
UN Secretary-Ge



– Geoffrey Moore, Author of *Dealing with Darwin: How Great Companies Cope with Globalization and Commoditization*

Chemistry Education is Changing

Cognitive science informs us how students learn

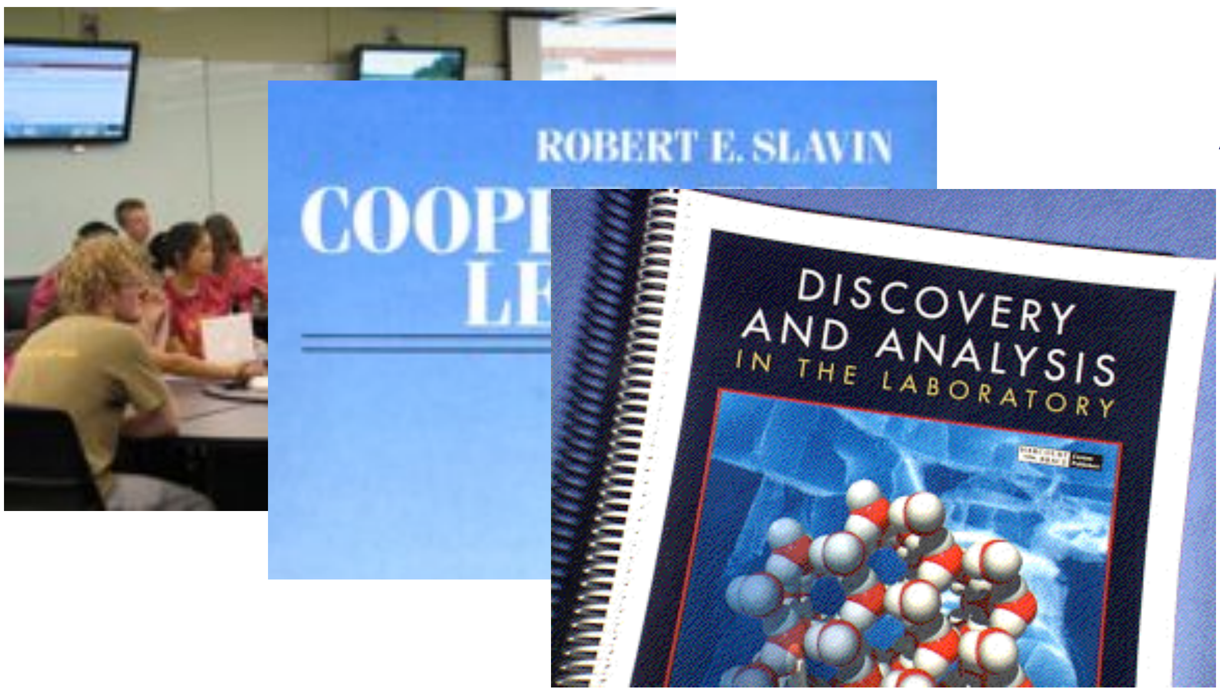


Alex Johnstone, 2009 ACS Award Recipient for Achievement in Research for the Teaching and Learning of Chemistry, *J. Chem. Ed.*, January 2010

Chemistry Education is Changing

Cognitive science informs us how students learn

Evidence-based pedagogical approaches improve student learning



Active Learning

Cooperative and Group Learning

Inquiry-Based Learning

Chemistry Students are Changing

Students are becoming increasingly diverse in gender, ethnicity, age, and educational background

CHEMISTRY GRADUATES BY GENDER

	TOTAL	MEN	WOMEN	% WOMEN
BACHELOR'S GRADUATES				
1997	11,184	6,238	4,946	44.2
1998	11,219	6,134	5,076	45.2
1999	10,979	6,012	4,967	45.2
2000	10,669	5,746	4,923	46.1
2001	10,323	5,409	4,914	47.6
2002	9,923	4,958	4,965	50.0
2003	10,068	5,100	4,968	49.3
2004	10,155	4,987	5,168	50.9
2005	10,947	5,264	5,683	51.9
2006	12,120	5,829	6,291	51.9
2007	12,888	6,472	6,416	49.8

NOTE: Counts are of graduates from schools with departments offering ACS-approved chemistry bachelor's programs. **SOURCE:** Annual reports of the ACS Committee on Professional Training

C&E News, Dec 15 2008, p 40

MAKEUP OF CHEMISTRY CLASSES

	BACHELOR'S		
	2004	2005	2006
African American	7.0%	6.5%	6.7%
Asian American	13.6	12.8	14.5
White, non-Hispanic	69.4	70.9	68.5
Native American	0.5	0.5	0.5
Hispanic	5.7	5.3	5.2
International	3.9	4.0	4.5

SOURCE: Annual reports of the ACS Committee on Professional Training

C&E News, Sept 17 2007, p 44

Chemistry Students are Changing

Students are becoming increasingly diverse in gender, ethnicity, age, and educational background

TABLE 1.
Percentage of Bachelor's and Master's Degree Recipients in 1999 and 2000 Who Attended Community College

44%	overall
37%	physical and related sciences
40%	engineering
42%	computer and math sciences
45%	social and related sciences
46%	life and related sciences

Tsapogas, J. The Role of Community Colleges in the Education of Recent Science and Engineering Graduates. NSF InfoBrief, April 2004. http://www.nsf.gov/statistics/infbrief/nsf04315/ (accessed on February 1, 2006).

Chemistry programs are likely to have increasing numbers of students and majors who take at least one chemistry course at a different institution. **Of all undergraduates, 57% attend more than one institution[1]**... Regardless of the the reasons for "swirling" between institutions, the number of students following alternative pathways in higher education is increasing.

[1]C. Adelman, Principle Indicators of Student Academic Histories in Postsecondary Education, 1972-2000, U.S. Dept. of Education, 2004

CPT Newsletter, Spring 2006

Chemistry Students are Changing

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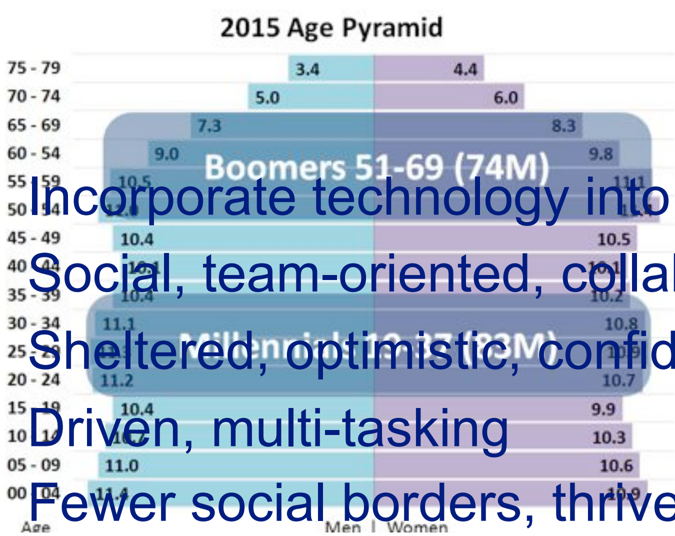
Millennials (born in 1980's and 90's) make up 27% of the US population and most of our students

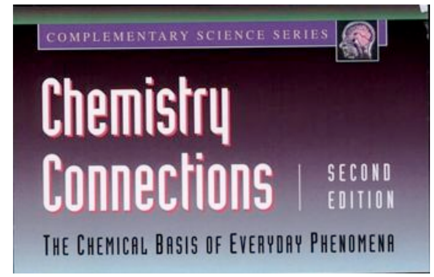


- Incorporate technology into lifestyle
- Social, team-oriented, collaborative
- Sheltered, optimistic, confident, special
- Driven, multi-tasking
- Fewer social borders, thrive on feedback
- Accepting, egalitarian, want to make a difference

Sources:
Leslie Wilson, *Teaching Millennial Students*, 2005
Michele Monaco and Malissa Martin, *Athletic Training Education Journal*, 2007

Innovations in Chemistry Education

Pedagogical approaches exist to improve student learning and student retention in chemistry and the physical sciences



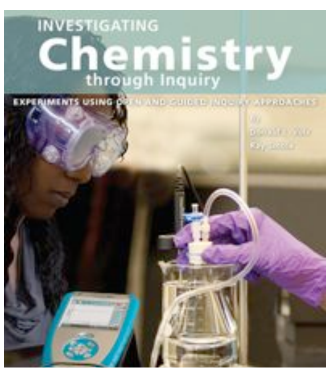
Case Studies

POGIL

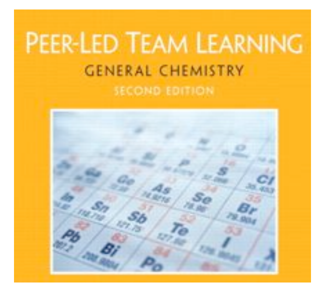
POGIL – Process Oriented Guided Inquiry Learning

CASPIE

CASPIE – Center for Authentic Science Practice in Education



Inquiry-Based Laboratories



PLTL – Peer Led Team Learning

CPR

Calibrated Peer Review

Innovations in Chemistry Education

Pedagogical approaches exist to improve student learning and student retention in chemistry and the physical sciences

Innovative programs are modifying their curriculum to better meet students needs

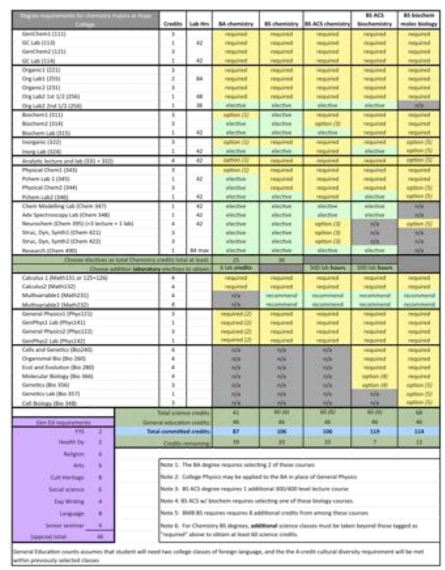
Length of First-Year General Chemistry Course

3%	0 semesters
37%	1 semester
19%	1-2 semesters
41%	2 semesters

Note: 34% offer organic I as a first-year spring course

S. Wettack, *Survey of 32 Liberal Arts College Chemistry Programs*, unpublished, 2009

Paths for Chemistry Majors



[illegible]	Credits	Lab Hrs	BA chemistry	BS chemistry	BS ACS chemistry	BS ACS biochemistry	BS biochem molec biology
GenChem1 (111)	3		required	required	required	required	required
GC Lab (113)	1	42	required	required	required	required	required
GenChem2 (121)	3		required	required	required	required	required
GC Lab (114)	1	42	required	required	required	required	required
Organic1 (221)	3		required	required	required	required	required
Org Lab1 (255)	2	84	required	required	required	required	required
Organic2 (231)	3		required	required	required	required	required
Org Lab2 1st 1/2 (256)	1	48	required	required	required	required	required
Org Lab2 2nd 1/2 (256)	1	36	elective	elective	elective	elective	n/a
Biochem1 (311)	3		option (1)	elective	required	required	required
Biochem2 (314)	3		elective	elective	option (3)	required	required
Biochem Lab (315)	1	42	elective	elective	elective	required	required
Inorganic (322)	3		option (1)	required	required	required	option (5)
Inorg Lab (324)	1	42	elective	elective	required	elective	option (5)
Analytic lecture and lab (331 + 332)	4	42	option (1)	required	required	required	option (5)
Physical Chem1 (343)	3		option (1)	required	required	required	required
Pchem Lab 1 (345)	1	42	elective	required	required	required	required
Physical Chem2 (344)	3		elective	required	required	required	option (5)
Pchem Lab2 (346)	1	42	elective	elective	required	elective	option (5)
Chem Modelling Lab (Chem 347)	1	42	elective	elective	elective	elective	n/a
Adv Spectroscopy Lab (Chem 348)	1	42	elective	elective	elective	elective	n/a
Neurochem (Chem 395) (=3 lecture + 1 lab)	4	42	elective	elective	option (3)	n/a	option (5)
Struc, Dyn, Synth1 (Chem 421)	3		elective	elective	option (3)	n/a	n/a
Struc, Dyn, Synth2 (Chem 422)	3		elective	elective	option (3)	n/a	n/a
Research (Chem 490)	1	84 max	elective	elective	elective	elective	n/a
Choose electives so total Chemistry credits total at least:			25	36			
Choose addition **laboratory** electives to obtain:			6 lab credits		500 lab **hours**	500 lab **hours**	
Calculus 1 (Math131 or 125+126)	4		required	required	required	required	required
Calculus2 (Math132)	4		required	required	required	required	required
Multivariable1 (Math231)	4		n/a	recommend	recommend	recommend	recommend
Multivariable2 (Math232)	4		n/a	recommend	recommend	recommend	recommend
General Physics1 (Phys121)	3		required (2)	required	required	required	required
GenPhys1 Lab (Phys141)	1		required (2)	required	required	required	required
General Physics2 (Phys122)	3		required (2)	required	required	required	required
GenPhys2 Lab (Phys142)	1		required (2)	required	required	required	required
Cells and Genetics (Bio240)	4		n/a	n/a	n/a	required	required
Organismal Bio (Bio 260)	4		n/a	n/a	n/a	required	required
Ecol and Evolution (Bio 280)	4		n/a	n/a	n/a	required	required
Molecular Biology (Bio 366)	4		n/a	n/a	n/a	option (4)	required
Genetics (Bio 356)	3		n/a	n/a	n/a	option (4)	option (5)
Genetics Lab (Bio 357)	1		n/a	n/a	n/a	n/a	option (5)
Cell Biology (Bio 348)	3		n/a	n/a	n/a	n/a	option (5)
Total science credits:			41	60 (6)	60 (6)	60 (6)	68
General education credits:			46	46	46	46	46
Total committed credits:			**87**	**106**	**106**	**119**	**114**
Credits remaining:			39	20	20	7	12

Gen Ed requirements	
FYS	2
Health Dy	2
Religion	6
Arts	6
Cult Heritage	8
Social science	6
Exp Writing	4
Language	8
Senior seminar	4
(approx) total	46

Note 1: The BA degree requires selecting 2 of these courses

Note 2: College Physics may be applied to the BA in place of General Physics

Note 3: BS ACS degree requires 1 additional 300/400 level lecture course

Note 4: BS ACS w/ biochem requires selecting one of these biology courses.

Note 5: BMB BS requires requires 8 additional credits from among these courses

Note 6: For Chemistry BS degrees, **additional** science classes must be taken beyond those tagged as "required" above to obtain at least 60 science credits.

General Education counts assumes that student will need two college classes of foreign language, and the the 4-credit cultural diversity requirement will be met within previously selected classes

ACS Approval Program

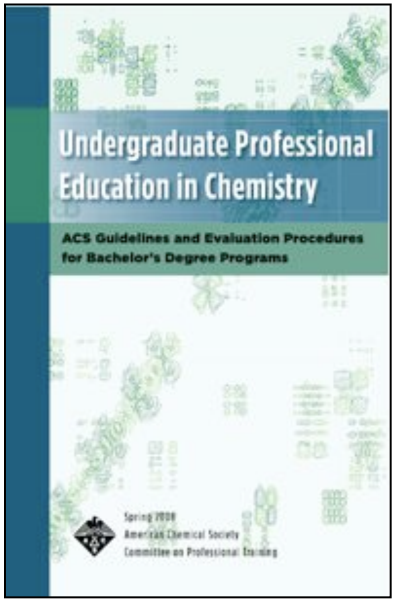
Administered by Committee on Professional Training

647 approved programs (196 research universities, 114 comprehensive universities, 337 baccalaureate colleges)

13,921 undergraduate chemistry graduates in 2007-08; 35% received an ACS-certified degree

Approved programs report annually and undergo review by ACS every five years

In response to changes in chemistry, education, and students, ACS Guidelines were revised in 2008



Overview of 2008 ACS Guidelines

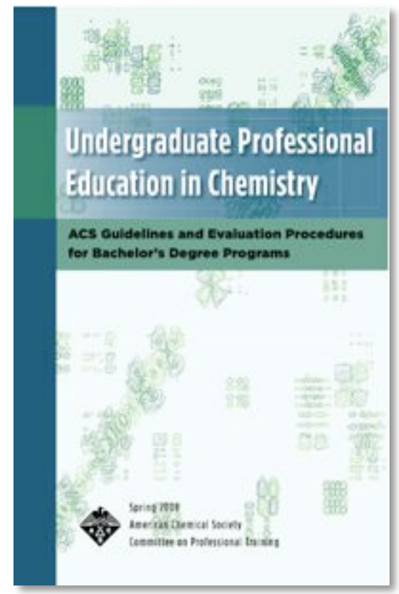
Institutional Environment
- Autonomous unit with control over faculty selection, curriculum, budget

Faculty and Staff
- Minimum of 4 FT faculty; at least 75% PhD's
- 15 contact hours maximum with flexibility

Infrastructure
- Instrumentation (NMR required)
- Computational software
- Chemical information resources (journals and Chem Abstracts)
- Physical plant and chemical safety

Curriculum
- Foundation and in-depth courses
- Degree tracks (replace options)
- Laboratory experience
- Undergraduate research

Student Skills
- Problem-Solving, Literature, Safety, Communication, Teamwork, Ethics
- Development of skills should be assessed



www.acs.org/cpt

Self-Evaluation
- Regular program self-evaluation to improve effectiveness

Procedures
- Initial approval
- Periodic review

ACS-Certified Chemistry Curriculum

General chemistry

0-2 sem general

Foundation courses

1 sem analytical
1 sem biochemistry
1 sem inorganic
1 sem organic
1 sem physical

In-depth courses

4 sem that build upon the foundation

Laboratory

400 hours beyond Gen Chem

Research

Can count for up to 180 lab hours with a comprehensive written report

Cognate courses

2 sem calculus
Mullti, lin alg, diff eq strongly rec
2 sem physics

Department-Defined Degree Track Examples

Chemistry

Gen Chem I and II

Foundation:

- Analytical Chem
- Biochemistry
- Inorganic Chem
- Organic Chem I
- Physical Chem I

In-Depth:

- Instrumental Analysis
- Organic Chem II
- Physical Chem II
- Advanced Elective

Biochemistry

Gen Chem I and II

Foundation:

- Analytical Chem
- Biochemistry I
- Inorganic Chem
- Organic Chem I
- Physical Chem

In-Depth:

- Biochemistry II
- Organic Chem II
- Molecular Biology
- Advanced Elective

Synthesis

Gen Chem I and II

Foundation:

- Analytical Chem
- Biochemistry
- 2 sem Integrated Synthesis (I,O)
- Physical Chem

In-Depth:

- Mechanisms
- Spectroscopy
- Polymers*
- Catalysis*

(* or Research)

A Thermodynamics Analogy

(by John Kozarich, CPT member)

$$\Delta G = \Delta H - T\Delta S$$

- ΔG → ACS-Certified Degree Track
- ΔH → Foundation Course Work
- $T\Delta S$ → In-Depth Course Work

Possible Department-Defined Degree Tracks

Materials

Gen Chem I and II

Foundation:

- Analytical Chem
- Biochemistry
- Solid State Structure & Synthesis (I)
- Organic Chem
- Physical Chem

In-Depth:

- Polymer Synthesis
- Electronic Structure/ Band Theory
- Biomaterial Engineering
- Surface Chemistry

Forensic Chem

Gen Chem I and II

Foundation:

- Analytical Chem
- Biochemistry
- Inorganic Chem
- Organic Chem
- Physical Chem

In-Depth:

- Instrumental Analysis
- Forensic Chemistry
- Molecular Genetics
- Metabolism/Toxicology

Art Conservation

Gen Chem I and II

Foundation:

- Analytical Chem
- Biochemistry
- Dyes & Pigments (I,O)
- Synthetic Chem (I,O)
- Physical Chem

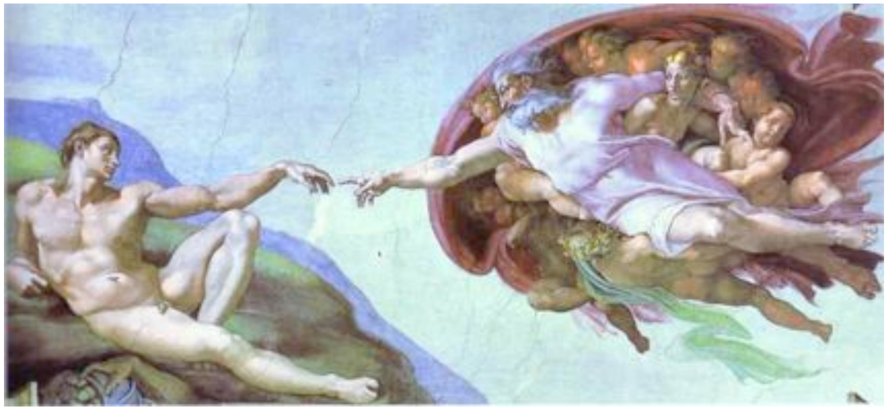
In-Depth:

- Art Conservation
- Polymers
- Fiber Chemistry
- Dyes & Pigments

Thoughts on Innovation

"The greatest danger for most of us is not that our aim is too high and we miss it, but that it is too low and we reach it."

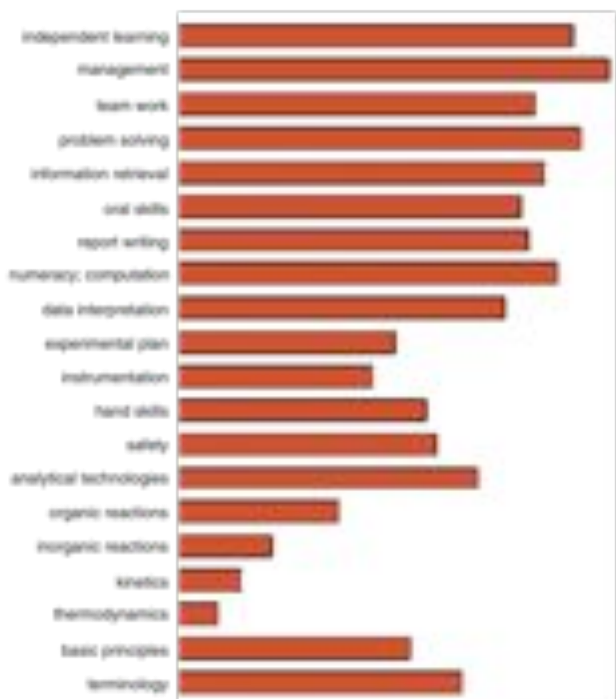
– Michelangelo



Student Skills

Students need to master skills beyond chemistry content to be come successful professionals

Relative comparison of skills required in chemistry workplace



Professional Skills

Laboratory Skills

Chemistry Content

S. Hanson and T. Overton, *Graduate Survey: A Pilot Study*, Physical Sciences Centre: Hull, UK 2009

Student Skills

Students need to master skills beyond chemistry content to be come successful professionals

Professional skills need to be learned and assessed within curriculum

- Problem-solving
- Chemical literature
- Laboratory safety
- Oral and written communication
- Working in teams
- Ethics

Program Self-Evaluation

An excellent program regularly evaluates its curriculum, pedagogy, faculty development, and infrastructure needs relative to the program's mission

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An excellent program regularly evaluates its curriculum, pedagogy, faculty development, and infrastructure needs relative to the program's mission

Self-evaluation results should be incorporated back into program

Self-evaluation is a process for continual improvement

ACS Committee on Professional Training, *Department Self-Evaluation Supplement*, 2008

The Guidelines are a Paradigm Shift to Promote Excellence, Rigor, and Innovation

- ACS Guidelines specify department characteristics that support excellence (faculty and infrastructure requirements)

- Chemistry departments develop rigorous and innovation curricula to support student needs and interest (foundation and in-depth courses; degree-tracks)

- Curriculum is centered on student learning rather than on faculty teaching (student skills; self-evaluation)

- Will require hard work by faculty and effective communication within departments, but could redefine how chemistry is taught !

Acknowledgements

Chemistry Community

Committee on Professional Training Members

CPT Members – 2008

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ACS, *Journal of Chemical Education*, *C&E News*

More Information

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