

Greener chemistry in the organic chemistry laboratory: Benefits and lessons learned

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<http://www.greennano.org>

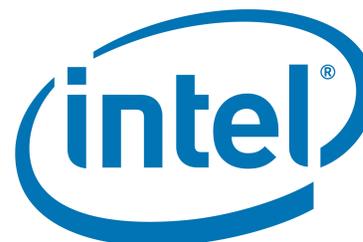


Excellent local examples of green innovation through chemistry in commerce



Sustainable Earth

By Staples^{TM/MC}



Are these “chemical” companies?

Solutions go far beyond choosing a safer alternative – innovation

They need new chemicals/materials, skilled workforce, leaders..

THE CHRONICLE OF HIGHER EDUCATION

July 10, 2009

Hot Academic Jobs of the Future: Try These Fields

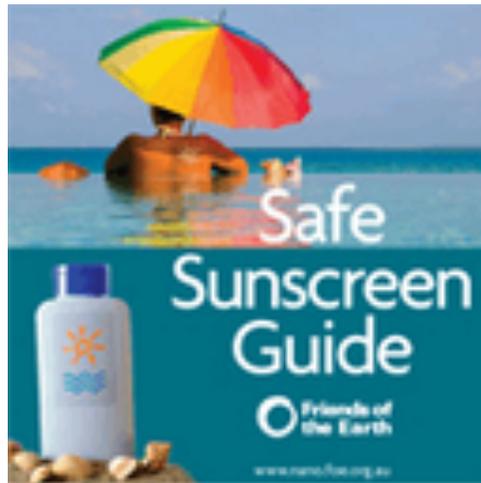
By LEE ROBERTS

“The following list is not a bible, and it's certainly not scientific. But here are some of the academic fields our experts believe will be "hot" over the coming decade:

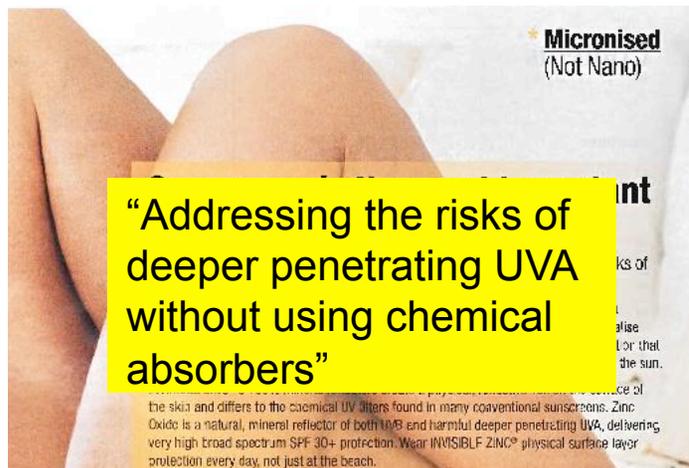
Green chemistry focuses on eliminating the use of toxic chemicals in chemistry without stifling scientific progress. Paul T. Anastas, a Yale University chemist, founded the field in 1991. As it grows in importance, more institutions are expected to offer master's degrees and doctorates. Among the universities with green-chemistry programs are Carnegie Mellon and Yale Universities and the Universities of Oregon, Scranton, and Massachusetts at Lowell.

Terry Collins, a chemistry professor at Carnegie Mellon who heads the university's Institute for Green Science, thinks the intellectual rationale for the field is strong. "It hasn't gotten a lot of federal support, but I think that's going to change," he says. One reason: Mr. Anastas has been nominated by President Obama to head the Environmental Protection Agency's Office of Research and Development.

Need to educate the public (either marketers or consumers) as well as chemists



Regulation of Nanotechnology in Consumer Products



Chem-free Sunscreens

• We scrutinize everything we put in our bodies—reading labels, checking food facts and counting calories. But what about what’s going on our bodies? By Victoria Barbatelli

Sunscreen ...chemical-free recipes made with organic minerals such as titanium dioxide and zinc oxide.”



Our organic lab curriculum wasn't meeting or anticipating these needs



Table 1 Starting Material Employed in Classic Organic Laboratory Syntheses 1902-1980

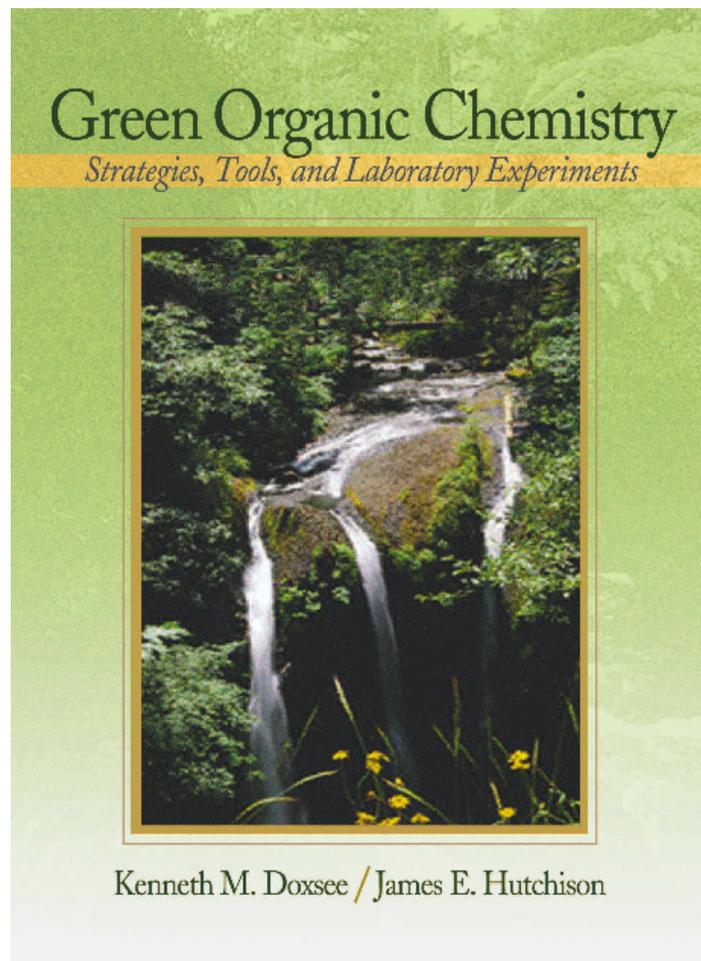
Date	Author	Acetanilide	4-Bromoacetanilide	Benzoin
		Aniline	Acetanilide	Benzaldehyde
1902	Levy, 4th ed.	46.2		50.0
1915	Cohen, 3rd ed.	25.0	5.0	25.0
1933	Adkins	28.0	13.5	10.0
1941	Fieser, 2nd ed.	18.2	13.5	25.0
1963	Adams	20.0	13.5	16.0
1980	Drust	10.0	5.2	10.0

Adapted from: From Microscale Organic Laboratory by D.W. Mayo, R.M. Pike and S.S. Butcher, 1985



Preparing students to pursue chemical research that brings solutions to sustainability challenges

The green chemistry curriculum pioneered at the UO has changed the way we address those needs



Modern chemistry, inquiry-based, safer lab, less waste, cheaper, enhanced learning environment, lower energy costs....

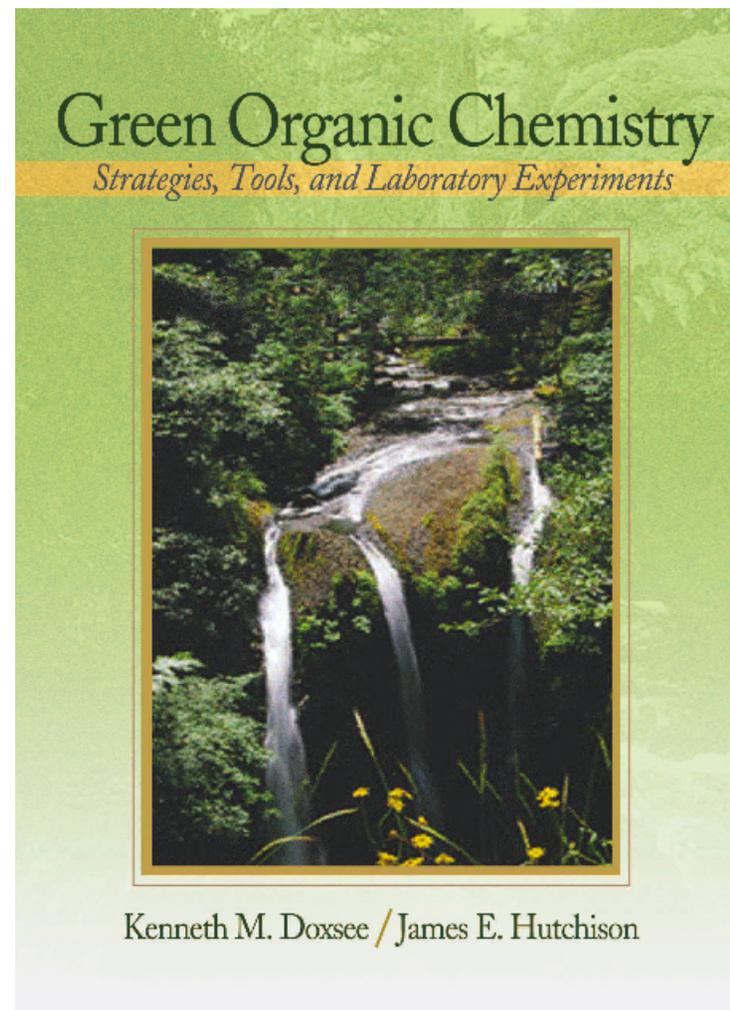
Green Organic Chemistry Laboratory Manual

19 Green Organic Chemistry Experiments

Plus....

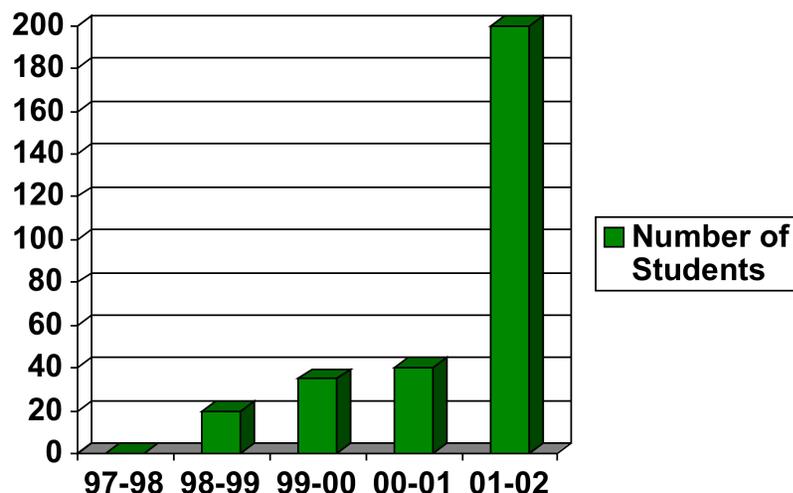
- Introduction
- Identification of Chemical Hazards
- Chemical Exposure and Environmental Contamination
- Evaluation of Chemical Hazards
- Introduction to Green Chemistry
- Alternative Solvents
- Alternative Reagents
- Reaction Design and Efficiency
- Alternative Feedstocks and Products

Target audience: Sophomore-level organic chemistry laboratory



2004 Brooks-Cole

Laboratory curriculum project implementation



Fall term

Synthesis, separations, spectroscopy

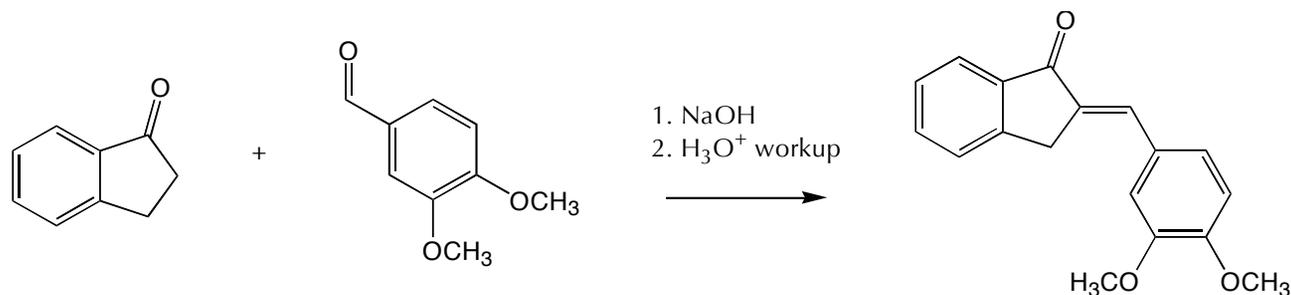
1. Solventless Aldol condensation
2. Bromination of an alkene
3. Preparation/distillation of cyclohexene
4. Synthesis of adipic acid
5. Oxidative coupling of alkynes
6. Gas phase porphyrin synthesis
7. Solvent effects on kinetics
8. Molecular mechanics modeling

Winter term

Synthesis, spectroscopy, applications

1. Electrophilic iodination with KI/NaOCl
2. Palladium-catalyzed aryl halide/alkyne coupling
3. Polymer-supported oxidation chemistry
4. Friedel-Crafts acylation of ferrocene
5. Thiamine-mediated benzoin condensation
6. Self-assembled monolayers/patterning
7. Combinatorial synthesis of antibiotics

Solventless Aldol Condensation



Chemical Concepts:

Melting point determination
and depression

Aldol condensation reaction

Recrystallization skills

Green Lessons:

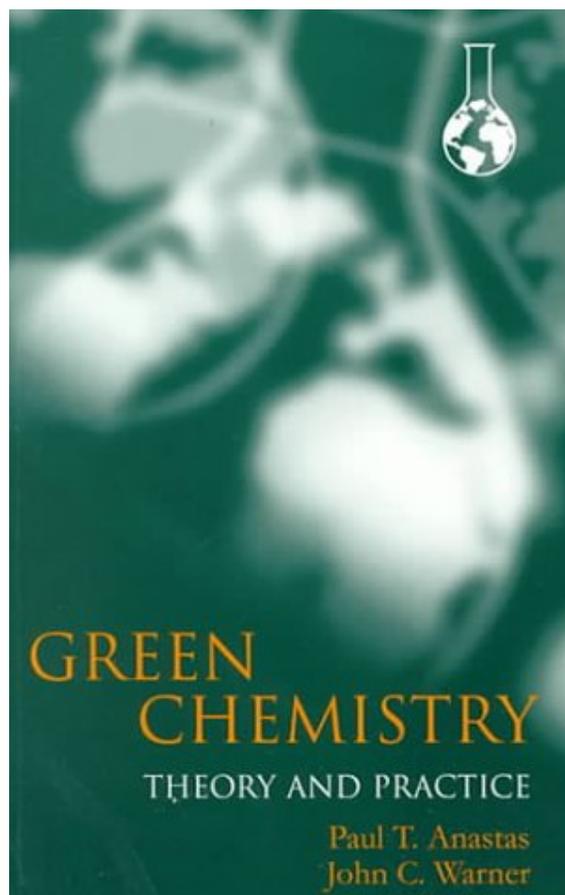
Solventless reactions

Atom economical reactions

Rothenberg, G.; Downie, A. P.; Raston, C. L.; Scott, J. L.
J. Am. Chem. Soc. **2001**, *123*, 8701-8708.

Raston, C. L.; Scott, J. L. *Green Chemistry* **2000**, *2*, 49-52.

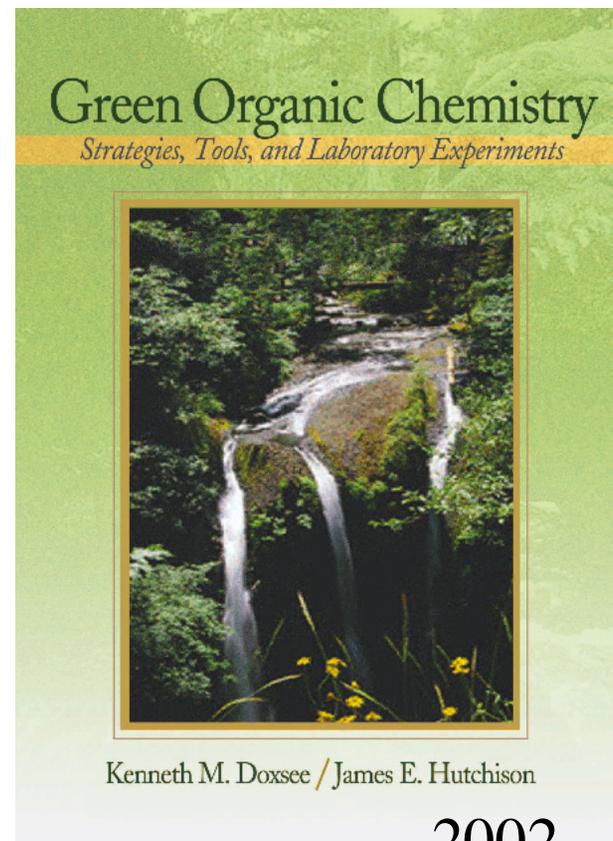
The number of resources has grown substantially since 1997



1998



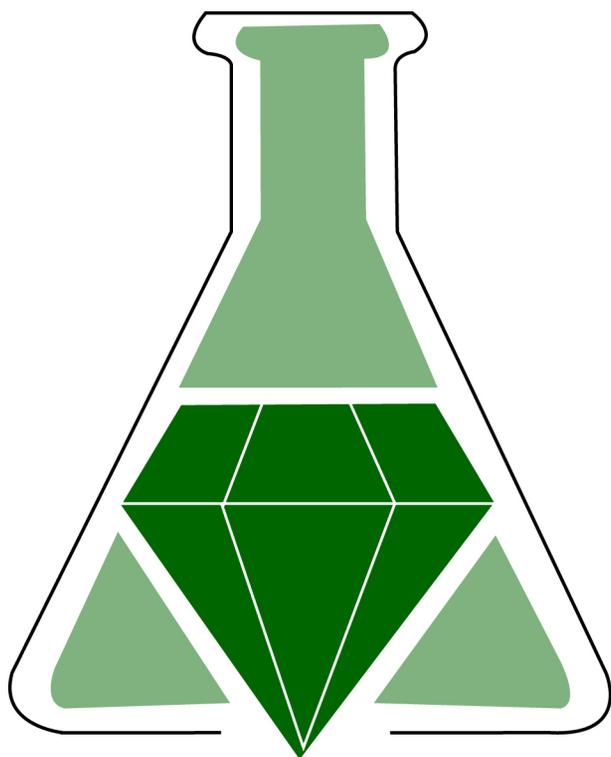
1999



2002

Materials from the ACS, JChEd and from Presidential Green Chemistry Challenge Awards (<http://www.epa.gov/greenchemistry/presgcc.html>)

GEMs: A living database for green chemistry education



GEMs for Chemists

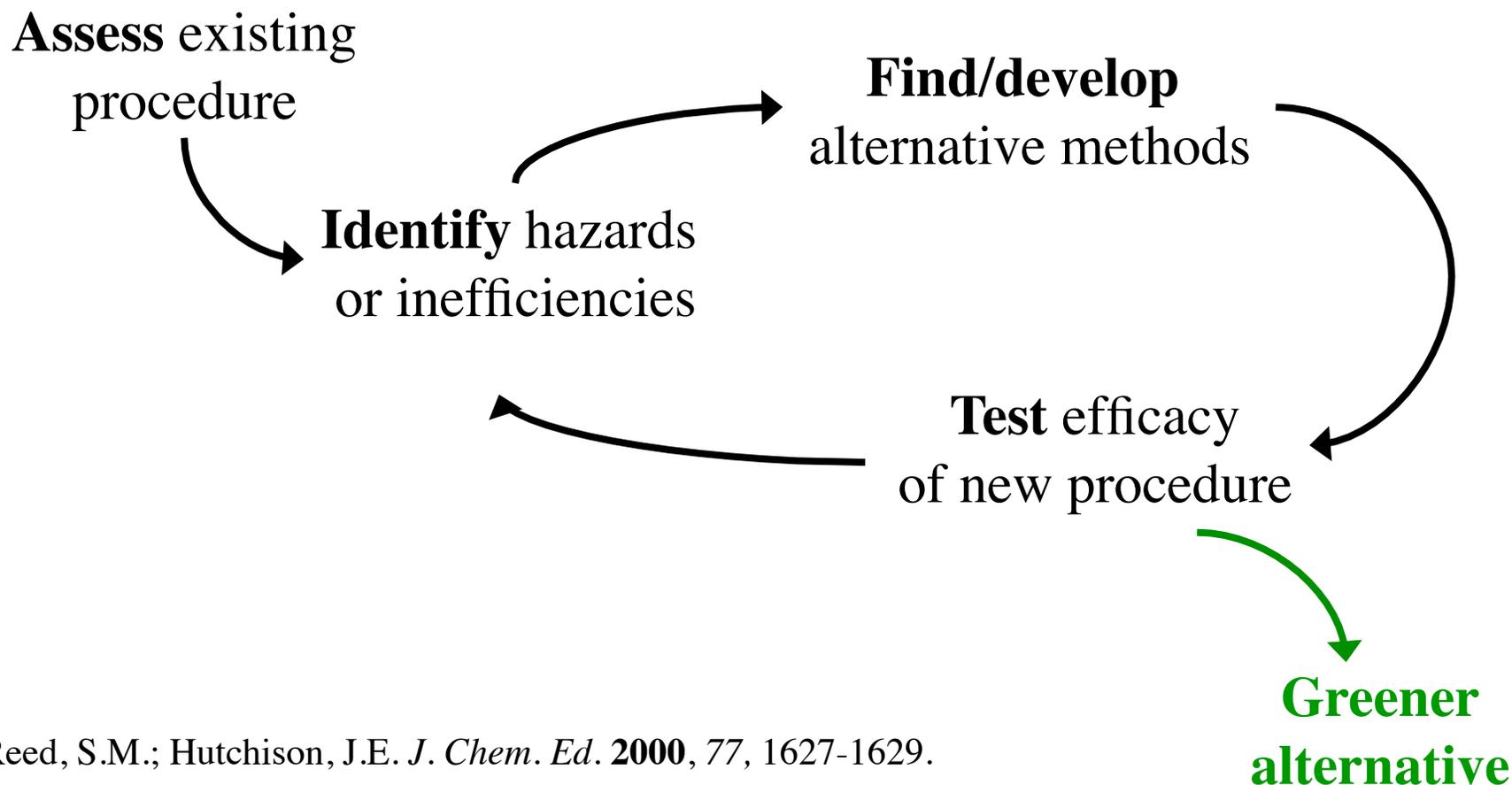
**Greener Education Materials
for Chemists**

*Goal: catalyze the incorporation of
green chemistry into the curriculum*

<http://greenchem.uoregon.edu>

Green chemistry appeals to students and builds problem-solving skills

"After taking this course I have a much better opinion of chemistry I feel like I am learning something that has an actual important application to the real world."



Faculty are engaged by it, too

“ (The students) are no longer looking at clock to leave as soon as possible, but staying late to finish what they’re doing. They have embraced the creative process of research that has been incorporated into the green chemistry curriculum.”

“It has completely revitalized my teaching and research interests; it has generated enthusiasm among my students and peers that is unparalleled in my career; it has brought service and outreach possibilities at the local and national level. In short, it's the best thing that's ever happened to my career.”

Principle based - provides flexibility to innovate
Opportunity for continuous improvement

There are many benefits for institutions

We are generating less **waste** and a less hazardous waste stream.

Winter term 2002 disposal numbers (14.2L of aqueous, 1L of flammable organic and 1kg of solid waste for 180 students)

The project has been great for University **public relations**

At least 30 articles have now been published around the world - higher profile has increased research funding

Enhances student **recruiting**

We have seen strong interest from undergrads and grads who want to be part of green chemistry - increased chem majors, graduate students

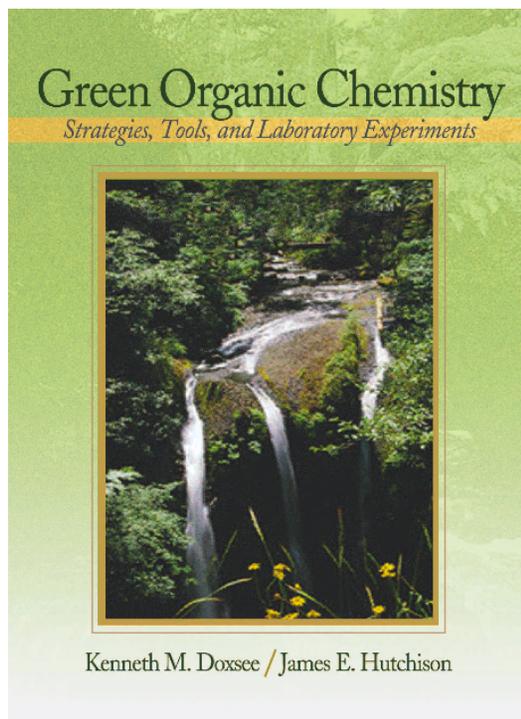
Opportunity to upgrade **curriculum and facilities** - energy savings (\$90k/yr)

University invested in a showcase lab facility to highlight the program

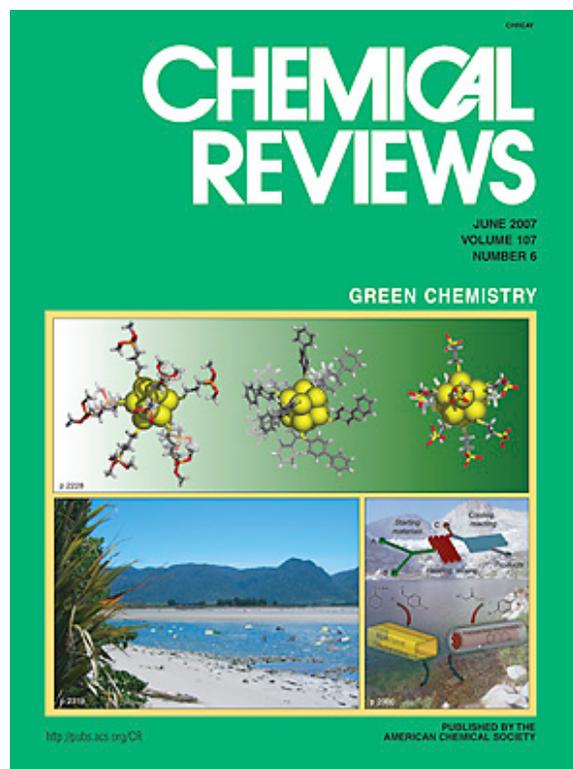
Improved **educational atmosphere**

The new lab setting is an excellent learning environment; multiscale glassware; new experimental techniques

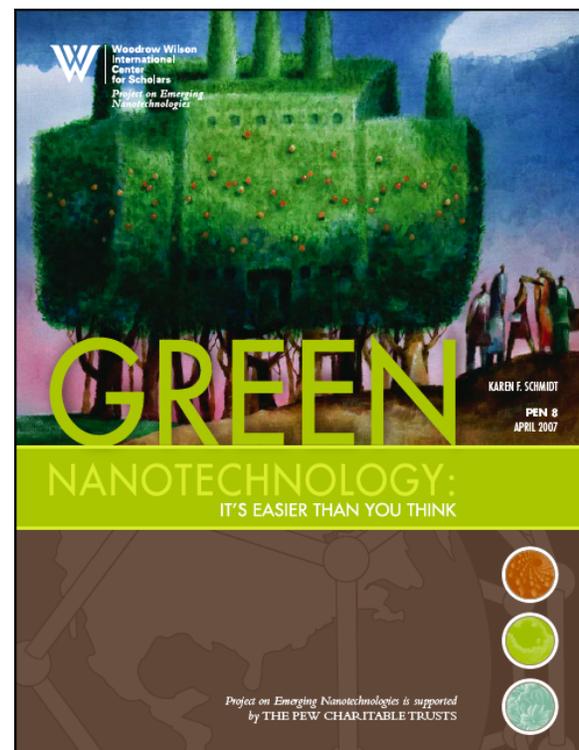
Green Chemistry is Now Infused Throughout Oregon's Research Community



Education



Research



Policy

1997: Green chemistry education efforts



Workshops for Faculty: 2001-present

Thinking about going GREEN ?

11th annual

Green Chemistry in Education Workshop

July 16, 2011

Hands-on workshop focusing on implementing green chemistry in the organic lab curriculum:

- try out new experiments
- learn approaches to incorporate green chemistry in your curriculum
- network with other educators in your region

Application deadline
for 2011 workshop:
February 15, 2011

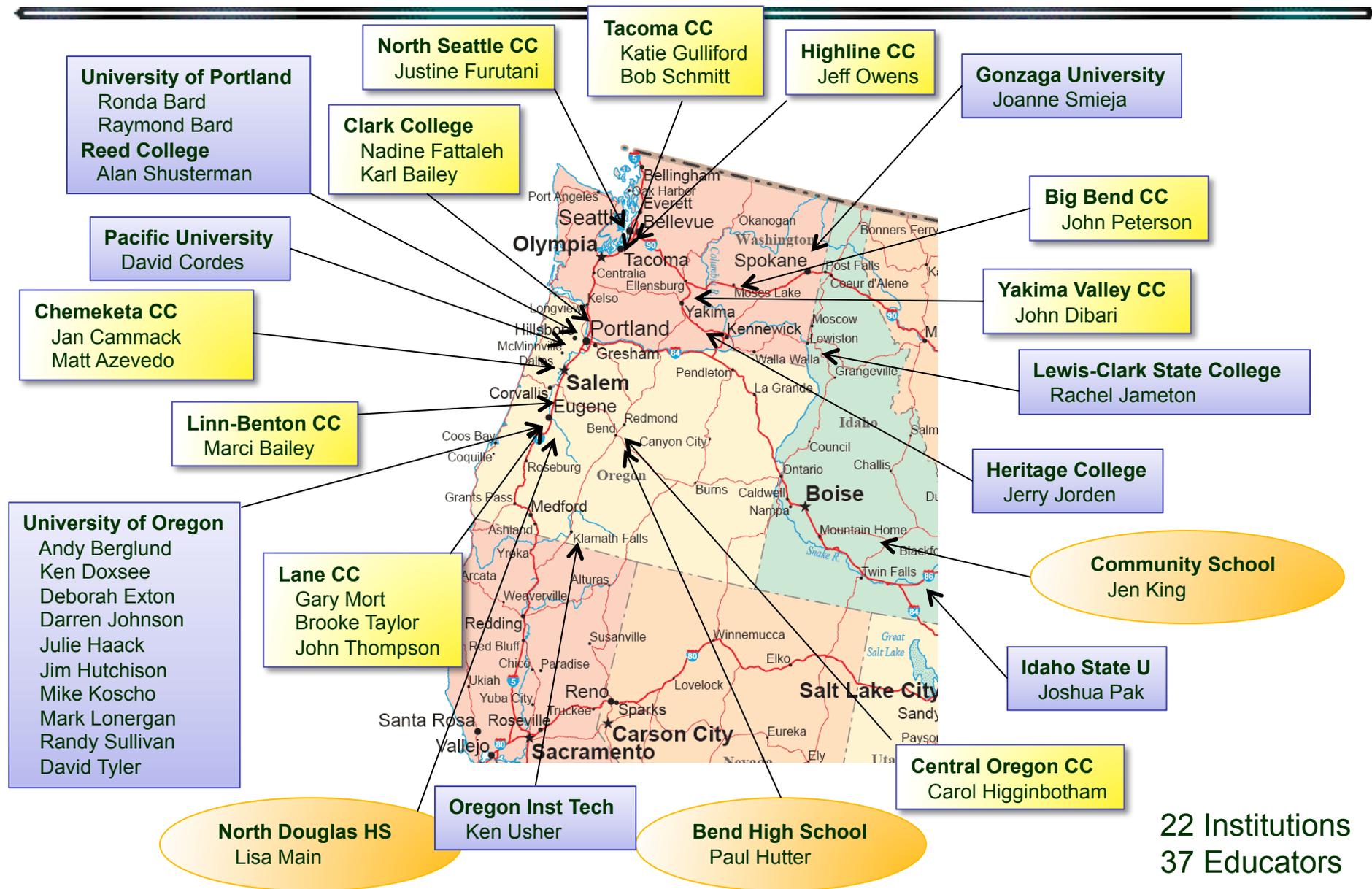
Sponsored by the UO, the NSF and
the NSF-sponsored Center for
Workshops in the Chemical Sciences

For more information see: <http://greenchem.uoregon.edu>

Today: Universities and colleges across the US (and around the world) are teaching green chemistry



Regional support for green chemistry educators



22 Institutions
37 Educators

Summary

- Interest in green chemistry is rising in academia and industry
- Green chemistry engages students and faculty – recruits new talent to the discipline
- Green chemistry has been appealing to educators because its principles they put their own stamp on it
- A wide array of greener materials are now available – for organic lab
- Think open source. Use available resources...don't reinvent the wheel/test tube....share your findings
- Challenge existing assumptions - why is *this* in the curriculum?
- Develop and test new materials...carefully
- Lean on the community for rapid (and successful) adoption



THERE IS NO FINISH LINE.



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Dr. Leif Brown

Mr. Gerd Woehrle

Students of CH337G/CH338G

Workshop participants

GCEdNet Members



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