

General Chemistry Innovations in Five-Minute Increments



Beth Vogel Taylor
Cathy Drennan

Bringing the “Why” and “Who” into General Chemistry

Observations and Concerns

- Undergraduates are interested in biology/medicine, but they don't see the connection to chemistry.



Bringing the “Why” and “Who” into General Chemistry

Observations and Concerns

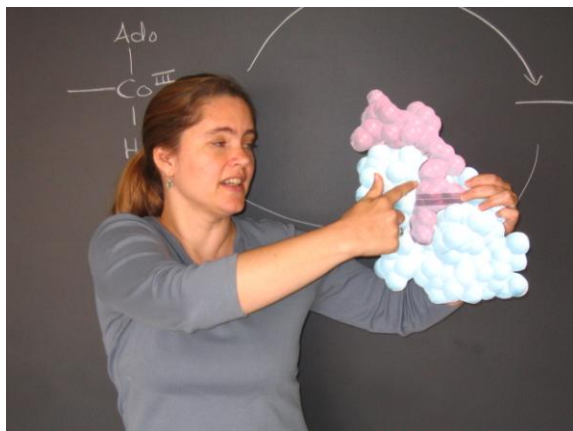
- Undergraduates are interested in biology/medicine, but they don't see the connection to chemistry.
- There is little room in most general chemistry curricula to add new units and few schools have the resources for creating a new interdisciplinary course.



Can small changes lead to meaningful improvements?

Can small changes lead to meaningful improvements?

Vehicle: Quick (2 to 5 minute) in-class examples relating each chemistry topic covered to applications in biology, medicine, and MIT research.



Chemistry Research @ MIT

Developing New Ways to Make Molecules

MIT Research article: [https://news.mit.edu/2018/08/22/chemistry-research-plant-chemicals](#)

Sarah O'Connor's lab seeks to manipulate the biosynthetic pathways in plants to make novel chemotherapeutics.

The image shows a screenshot of a MIT news article titled 'Developing New Ways to Make Molecules'. The article discusses how Sarah O'Connor's lab is using genetic engineering to modify plants to produce novel chemotherapeutics. A 3D molecular model of a complex organic molecule is shown at the bottom right.

Chemistry topic: polar covalent bonds

Identifying polar bonds in vitamins:

$\chi_H = 2.2$
 $\chi_C = 2.6$
 $\chi_N = 3.0$
 $\chi_O = 3.4$

Which is the more polar molecule?
A) Vitamin A
★ B) Vitamin B9 (folic acid)

vitamin A

vitamin B9 (folic acid)

The image shows the chemical structures of Vitamin A and Vitamin B9 (folic acid). Vitamin A is a long-chain polyene with a terminal hydroxyl group. Vitamin B9 is a complex heterocyclic structure with multiple nitrogen and oxygen atoms. Electronegativity values are listed for H (2.2), C (2.6), N (3.0), and O (3.4). A star is placed next to the label for Vitamin B9.

Vehicle: A series of short videos illustrating the “Faces of Chemistry at MIT”.

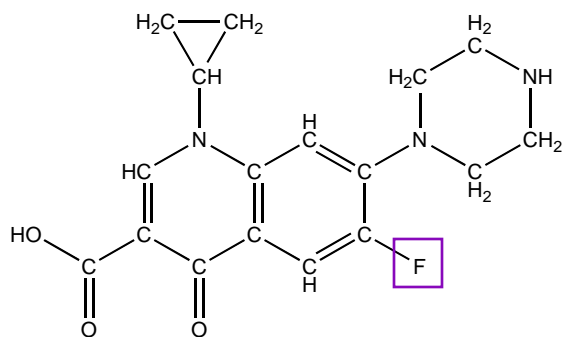


What do our lecture examples look like?

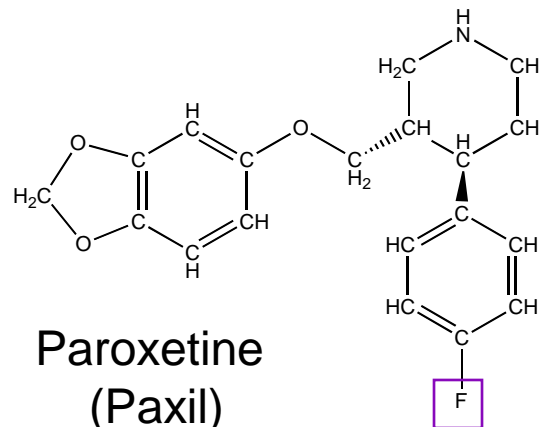
What do our lecture examples look like?

Chemistry topic: oxidation and reduction

Carbon-fluorine bonds in drugs



Ciprofloxacin (Cipro)
broad-spectrum antibiotic



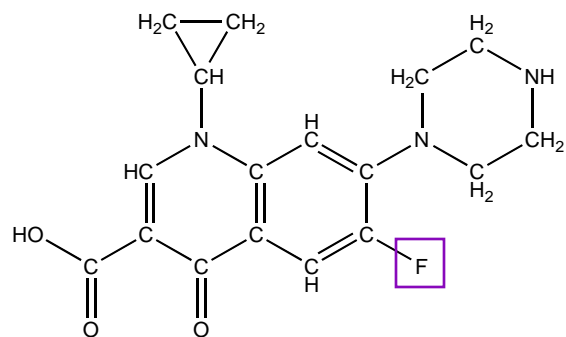
Paroxetine
(Paxil)
antidepressant

Replacing a C-H bond with a C-F bond can make a drug candidate more **electron poor**.

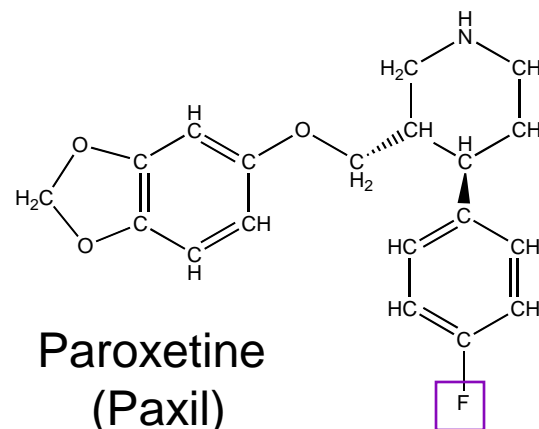
What do our lecture examples look like?

Chemistry topic: oxidation and reduction

Carbon-fluorine bonds in drugs



Ciprofloxacin (Cipro)
broad-spectrum antibiotic



Paroxetine
(Paxil)
antidepressant

An electron-poor drug is _____.



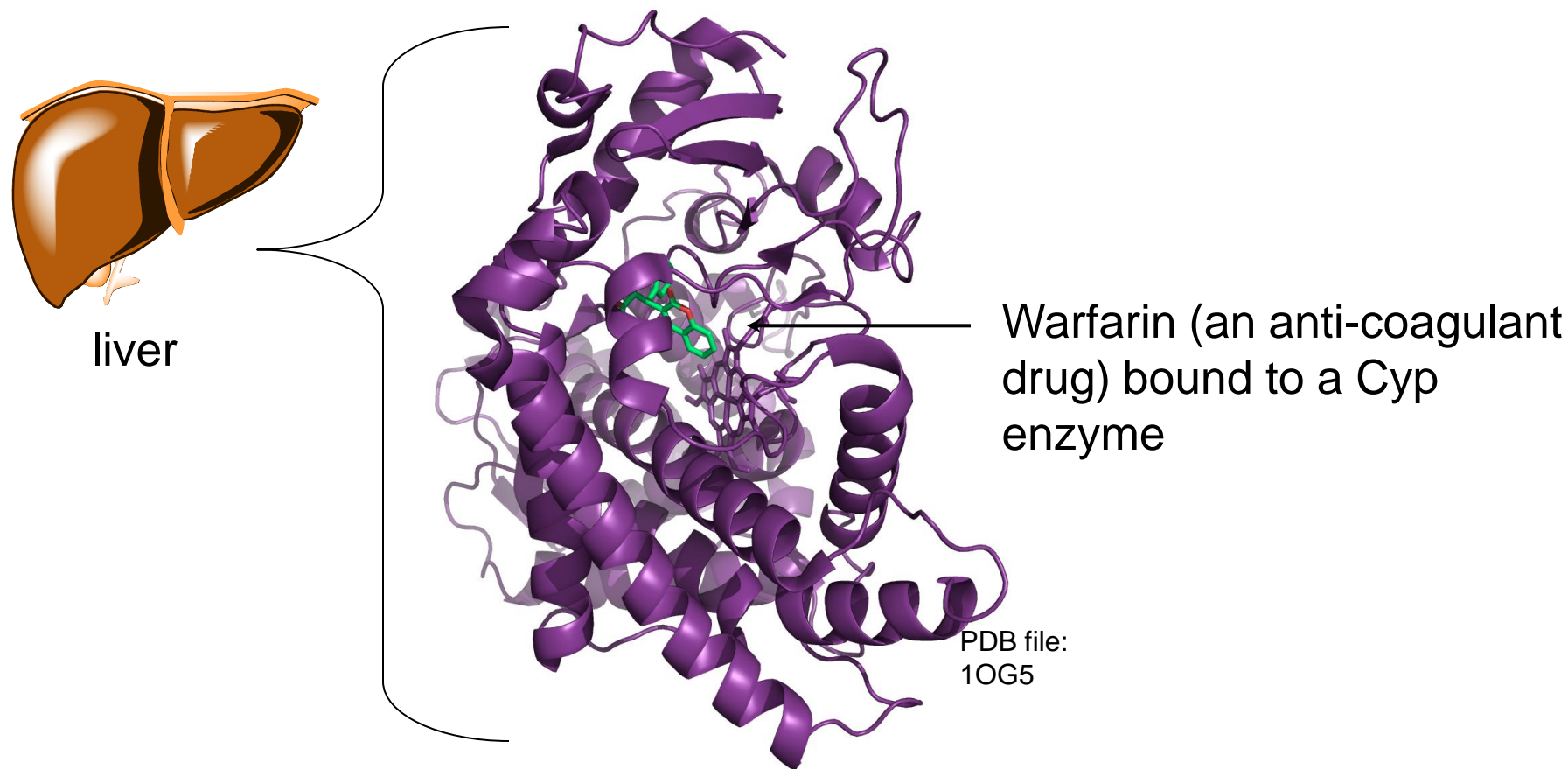
A) harder to oxidize

B) easier to oxidize

C) neither harder nor easier to oxidize than an electron-rich version of the drug

What do our lecture examples look like?

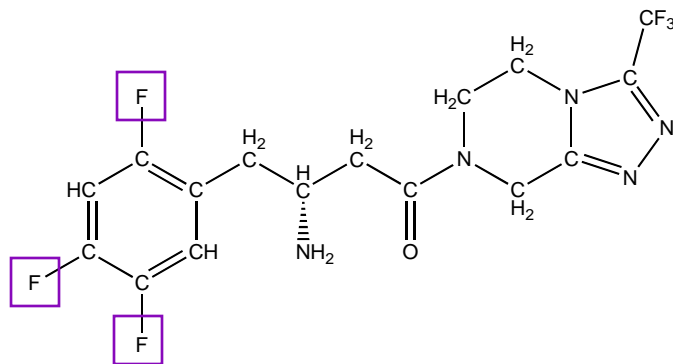
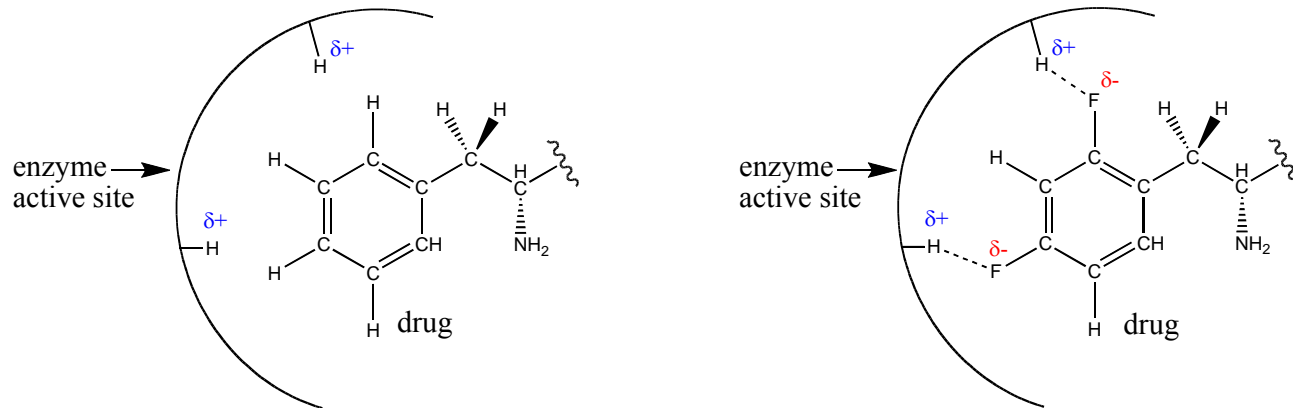
Cyp enzymes in the liver **oxidize** small molecules (such as drugs!) for excretion from the body



Fluorination can increase a drug's metabolic stability.

Biology-related examples create links between topics

As **hydrogen-bond** acceptors, F atoms can also lead to tighter drug binding in the active site of a target enzyme.



Sitagliptin (Januvia)
anti-diabetic
FDA approved in 2006

Assessing the impact of biology-related examples

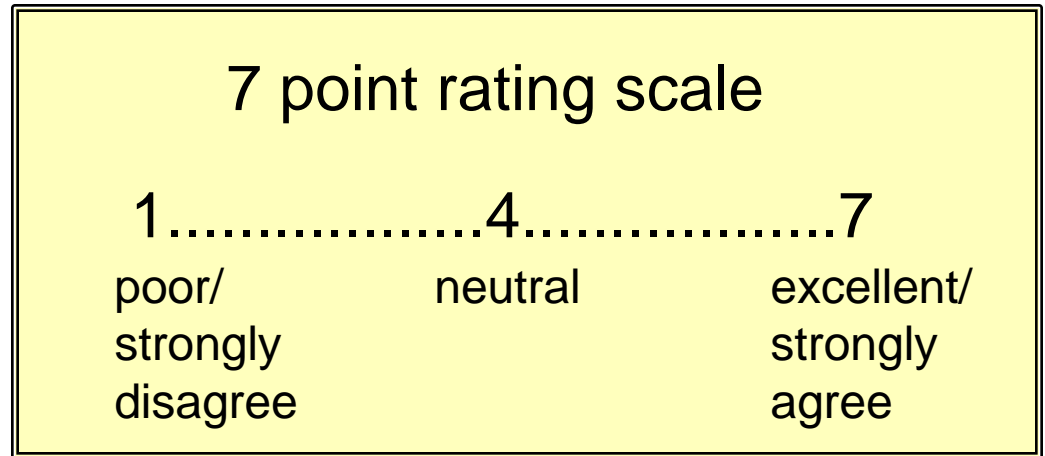
Assessing the impact of biology-related examples

Teaching and Learning Laboratory at MIT



Rudy Mitchell, Ed.D.

Associate Director for Assessment and Evaluation



- ✓ 15-minute online retrospective surveys
- ✓ MIT standard subject evaluations

(magic number of \$15 for ~80% student response rate)

Assessing the impact of biology-related examples

Following the course, freshman reported an interest in chemistry and a recognition of the relationship between chemistry and biology.

	Mean (SD)	N
S2A. I find chemistry interesting.	5.75 (1.27)	343
S2B. I would like to learn more chemistry.	5.52 (1.54)	341
S2C. In order to understand biology well, one must know some chemistry.	6.13 (0.96)	343
S2D. Chemistry is relevant to the field of biology.	6.34 (0.74)	343
S2E. Chemistry is relevant to medicine and other health care professions.	6.59 (0.63)	342
S2F. Knowing chemistry is of minimal value unless a student intends to major in chemistry or a related discipline.	2.57 (1.36)	342

Students credited the course for contributing to their positive views and attitudes.

ie. 86% of the class reported that lecture examples helped them see connections between biology and chemistry.

Assessing the impact of biology-related examples

MIT subject evaluations enabled direct comparison with years prior to course innovations.

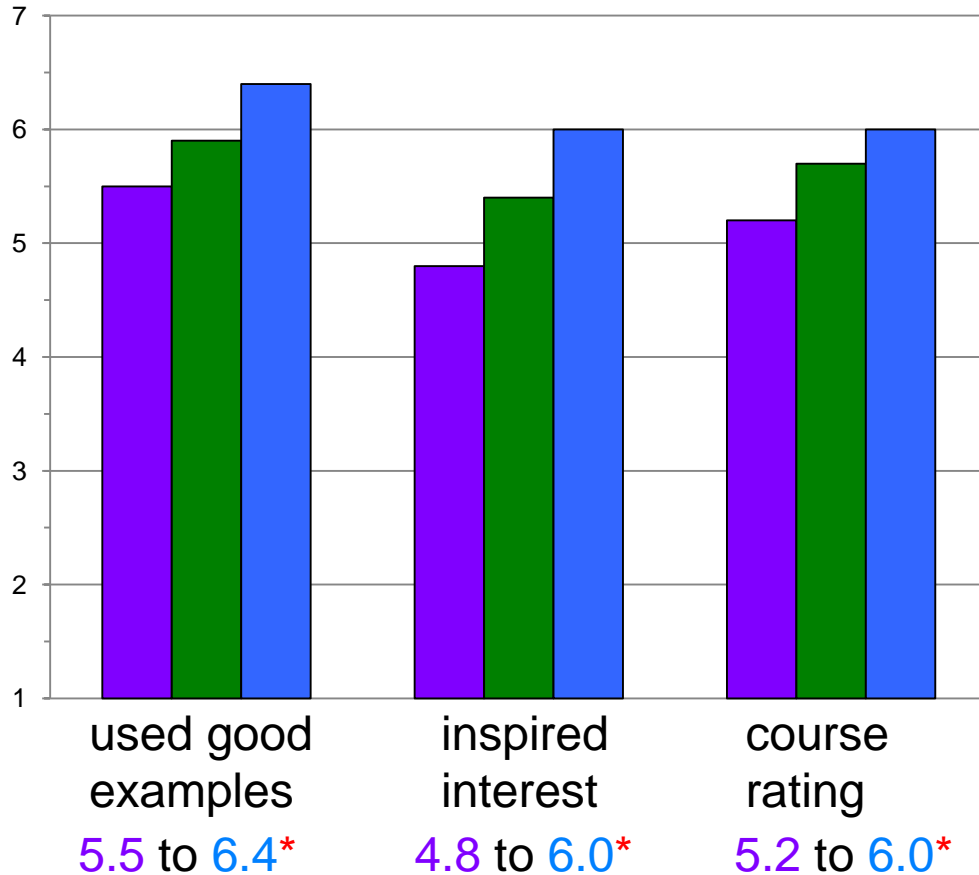
2006: no bio-related examples (N=135)

2007: bio-related examples throughout half of the course (N=198)

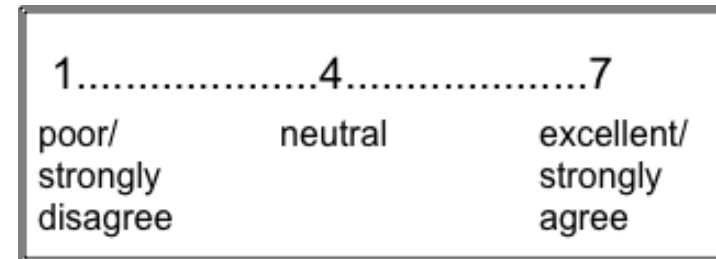
2008: biology-related examples throughout the course (N=160)

Assessing the impact of biology-related examples

MIT subject evaluations enabled direct comparison with years prior to course innovations.

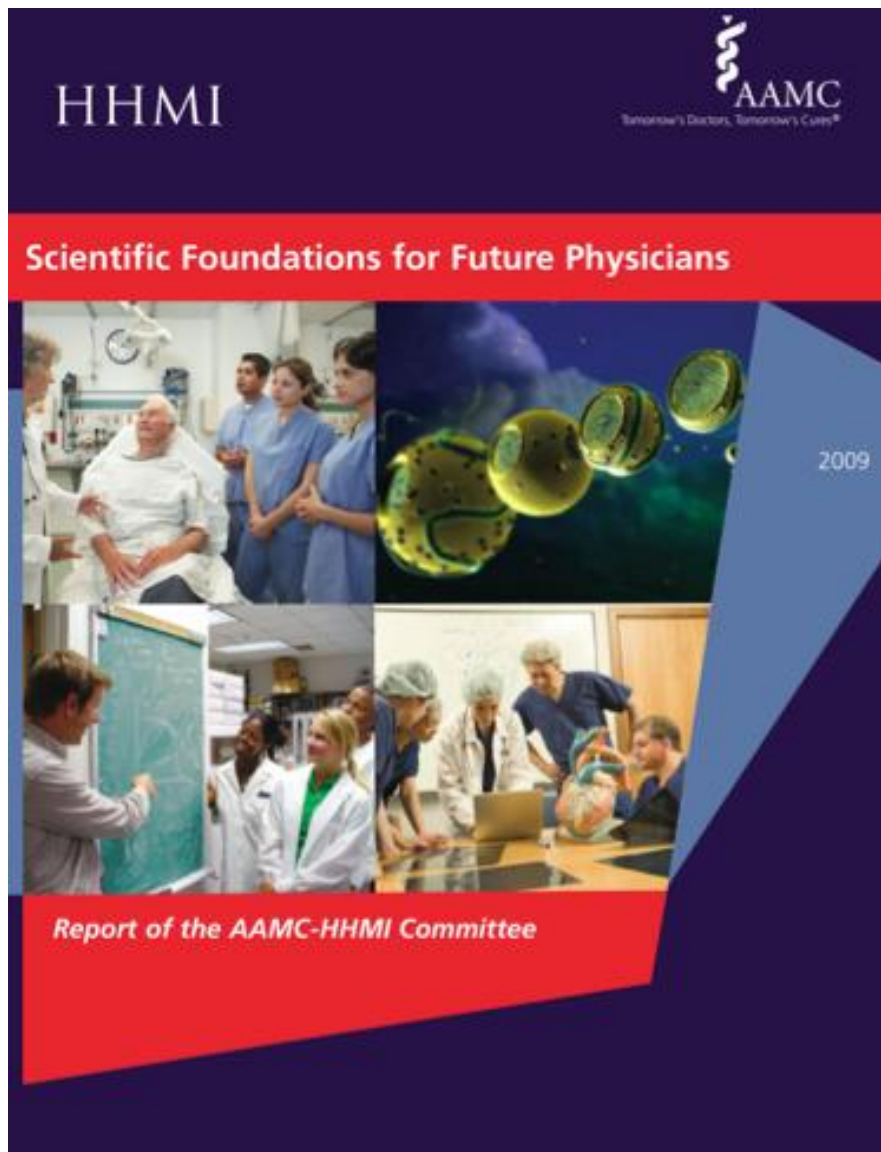


- 2006: no bio-related examples (N=135)
- 2007: bio-related examples throughout half of the course (N=198)
- 2008: biology-related examples throughout the course (N=160)



*indicates statistical significance

Assessing the impact on specific target groups



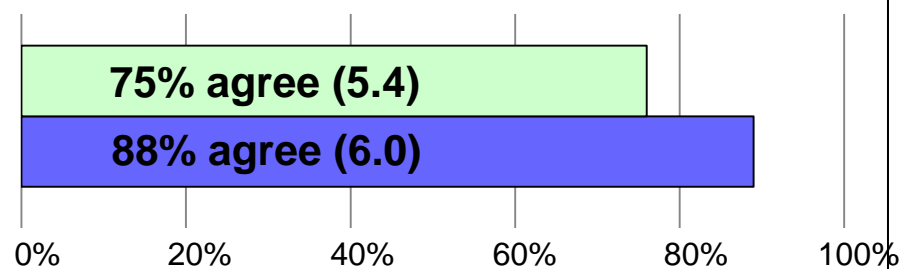
Assessing the impact on specific target groups

Pre-medical students (28% of the class)

- General chemistry *without* biology-related examples (N = 62)
- General chemistry *with* biology-related examples (N = 132)

As a result of this course...

I see the relevance of chemical principles to biology, medicine, and health care.*



“Subject content was interesting and I LOVED the connections to biology.”

“...made me love chemistry”

* statistically significant difference between cohorts

1 4 7
strongly disagree neutral strongly agree

Assessing the impact on specific target groups

Pre-medical students (28% of the class)

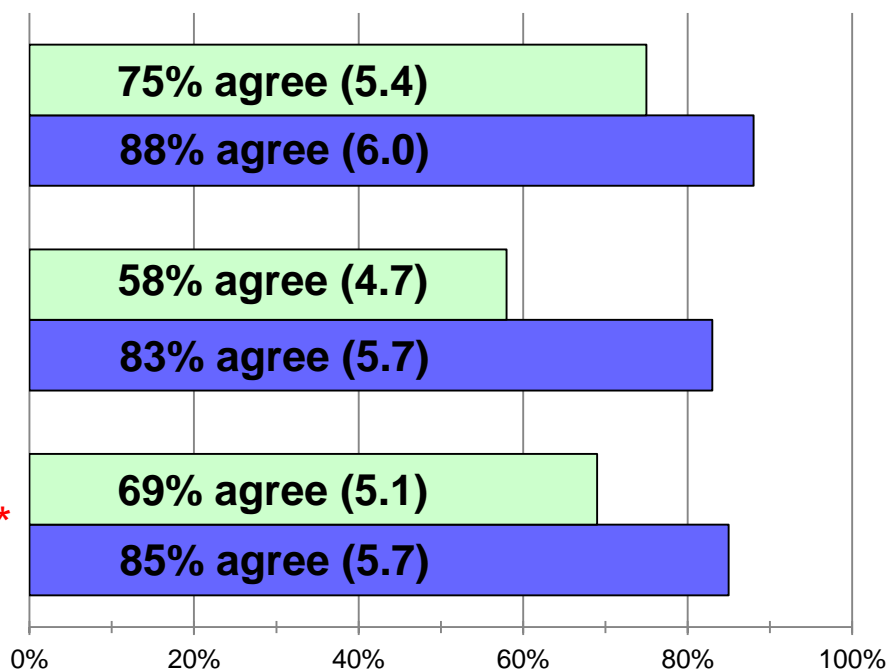
- General chemistry *without* biology-related examples (N = 62)
- General chemistry *with* biology-related examples (N = 132)

As a result of this course...

I see the relevance of chemical principles to biology, medicine, and health care.*

my **interest** in chemistry increased.*

I am interested in **learning more** chemistry.*



* statistically significant difference between cohorts

1 4 7
strongly disagree neutral strongly agree

Assessing the impact on specific target groups

Biology-related majors (59% of the class)

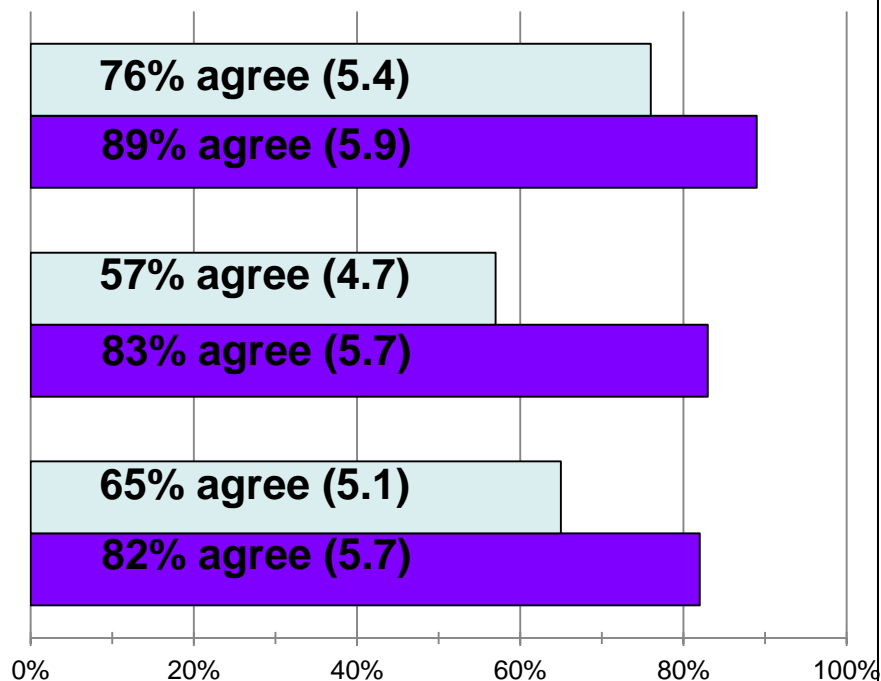
- General chemistry *without* biology-related examples (N = 99)
- General chemistry *with* biology-related examples (N = 308)

As a result of this course...

I see the relevance of chemical principles to biology, medicine, and health care.*

my **interest** in chemistry increased.*

I am interested in **learning more** chemistry.*



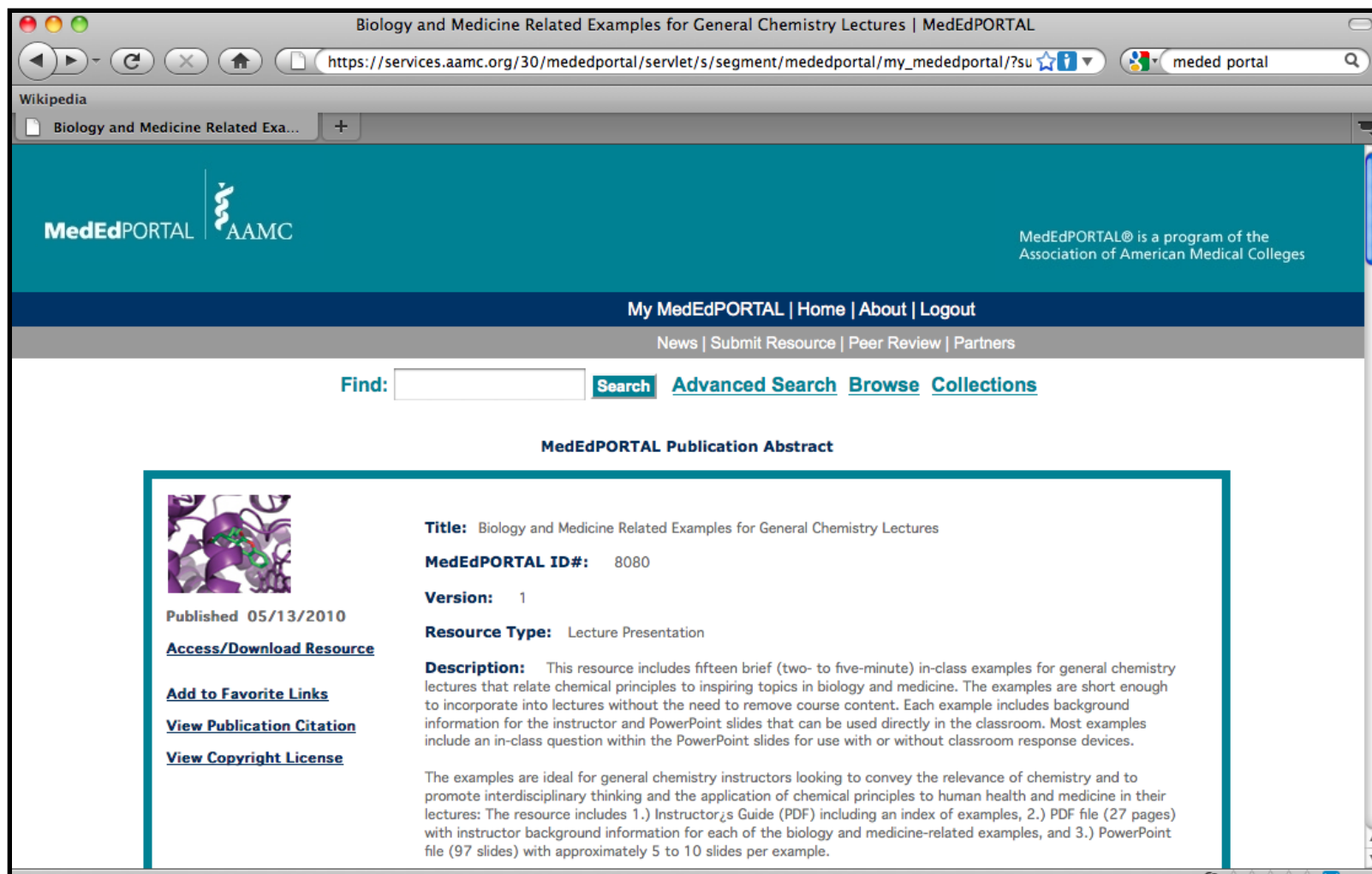
* statistically significant difference between cohorts

1 4 7
strongly disagree neutral strongly agree

Dissemination of resources: reaching teachers

MedED PORTAL

Our medicine-related examples for general chemistry were selected to pilot a site with teaching resources for pre-med courses.



The screenshot shows a web browser window displaying the MedEdPORTAL website. The browser's address bar shows the URL: https://services.aamc.org/30/mededportal/servlet/s/segment/mededportal/my_mededportal/?su. The website header features the MedEdPORTAL logo and the AAMC logo. Below the header, there is a navigation menu with links for "My MedEdPORTAL", "Home", "About", "Logout", "News", "Submit Resource", "Peer Review", and "Partners". A search bar is present with the text "Find:" and a search button. The main content area displays a "MedEdPORTAL Publication Abstract" for the resource "Biology and Medicine Related Examples for General Chemistry Lectures". The abstract includes a thumbnail image of a molecular structure, the title, MedEdPORTAL ID# (8080), Version (1), and Resource Type (Lecture Presentation). The description states that the resource includes fifteen brief in-class examples for general chemistry lectures that relate chemical principles to inspiring topics in biology and medicine. The examples are short enough to incorporate into lectures without the need to remove course content. Each example includes background information for the instructor and PowerPoint slides that can be used directly in the classroom. Most examples include an in-class question within the PowerPoint slides for use with or without classroom response devices. The examples are ideal for general chemistry instructors looking to convey the relevance of chemistry and to promote interdisciplinary thinking and the application of chemical principles to human health and medicine in their lectures: The resource includes 1.) Instructor's Guide (PDF) including an index of examples, 2.) PDF file (27 pages) with instructor background information for each of the biology and medicine-related examples, and 3.) PowerPoint file (97 slides) with approximately 5 to 10 slides per example.

Biology and Medicine Related Examples for General Chemistry Lectures | MedEdPORTAL

https://services.aamc.org/30/mededportal/servlet/s/segment/mededportal/my_mededportal/?su

Wikipedia

Biology and Medicine Related Exa... +

MedEdPORTAL | AAMC

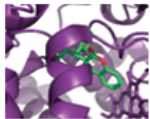
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MedEdPORTAL Publication Abstract



Title: Biology and Medicine Related Examples for General Chemistry Lectures

MedEdPORTAL ID#: 8080

Version: 1

Resource Type: Lecture Presentation

Description: This resource includes fifteen brief (two- to five-minute) in-class examples for general chemistry lectures that relate chemical principles to inspiring topics in biology and medicine. The examples are short enough to incorporate into lectures without the need to remove course content. Each example includes background information for the instructor and PowerPoint slides that can be used directly in the classroom. Most examples include an in-class question within the PowerPoint slides for use with or without classroom response devices.

The examples are ideal for general chemistry instructors looking to convey the relevance of chemistry and to promote interdisciplinary thinking and the application of chemical principles to human health and medicine in their lectures: The resource includes 1.) Instructor's Guide (PDF) including an index of examples, 2.) PDF file (27 pages) with instructor background information for each of the biology and medicine-related examples, and 3.) PowerPoint file (97 slides) with approximately 5 to 10 slides per example.

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Dissemination of resources: reaching teachers

MedED PORTAL

Our medicine-related examples for general chemistry were selected to pilot a site with teaching resources for pre-med courses.

Slides_for_Biology_and_Medicine_Related_Examples.ppt

7 Chemistry topic: polar covalent bonds
A bond is considered polar covalent if the electronegativity (χ) difference ≥ 0.5

H-H bond $\chi_H = 2.2$ non-polar

H-Cl bond $\chi_H = 2.2$ $\chi_{Cl} = 3.2$ polar

H-C bond $\chi_H = 2.2$ $\chi_C = 2.6$ non-polar

8 Chemistry topic: polar covalent bonds
Identifying polar bonds in vitamins:

$\chi_H = 2.2$
 $\chi_C = 2.6$
 $\chi_N = 3.0$
 $\chi_O = 3.4$

Which is the more polar molecule?
A) Vitamin A
B) Vitamin B9 (folic acid)

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10 Chemistry topic: polar covalent bonds
Identifying polar bonds in vitamins:

$\chi_H = 2.2$
 $\chi_C = 2.6$
 $\chi_N = 3.0$
 $\chi_O = 3.4$

Folic acid (B9) is much more polar than vitamin A.

Normal View Slide 8 of 97

For each example:

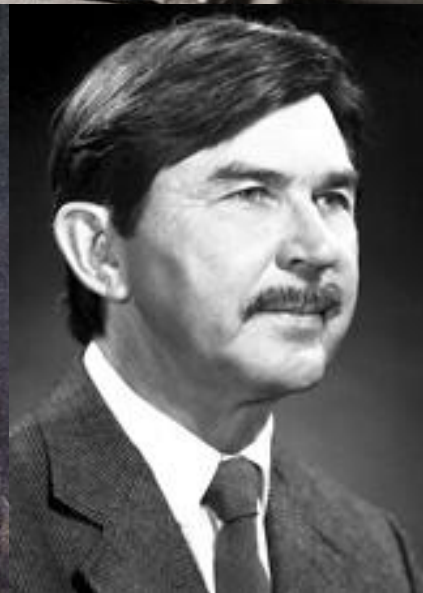
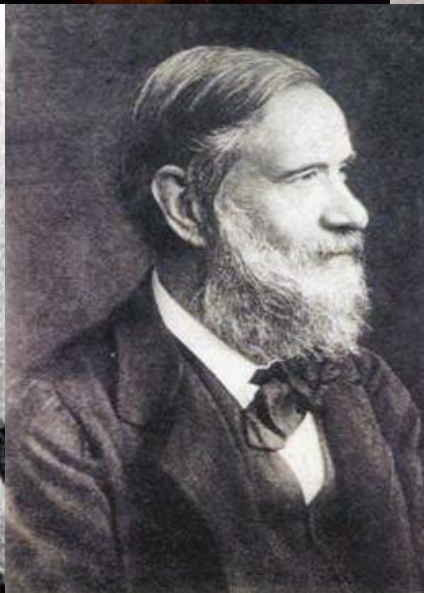
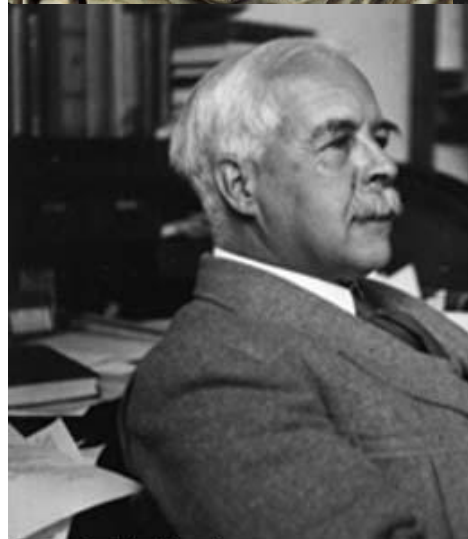
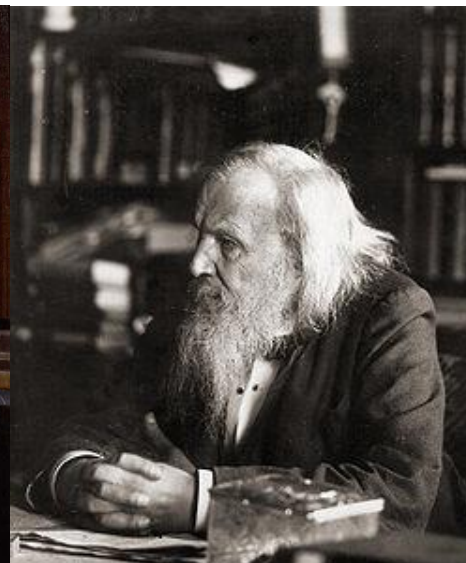
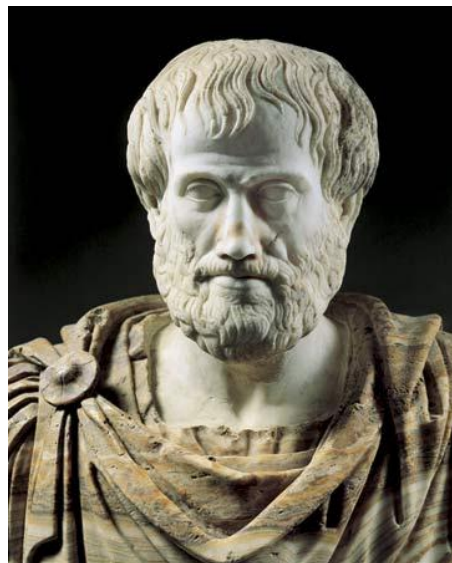
- 3 to 5 slides
- one concept-based chemistry question
- background info. for the instructor

Can small changes lead to meaningful improvements?

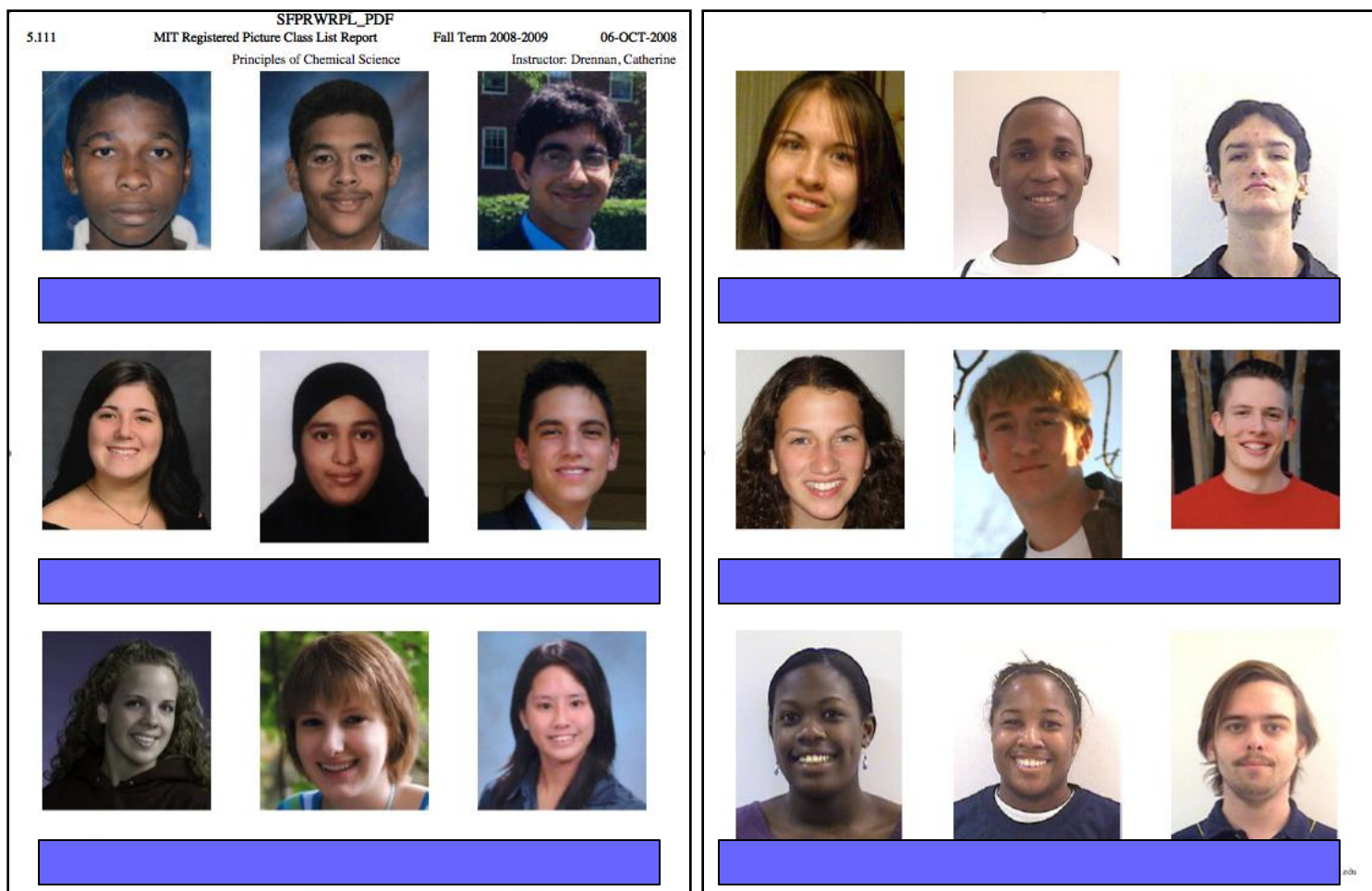
Vehicle: A series of short videos illustrating the “Faces of Chemistry at MIT”.



The “Who” of Chemistry (pictures from 5.111 “lecture 1”)



The “Who” of Chemistry (our students)



33%* of course 5.111 (general chemistry) freshmen identify as underrepresented minority students.

*averaged over Fall 2007-2010 and Spring 2010-2011 semesters (N = 597)

How do we increase the impact on URM students / women?

Inspiration from discussions and evaluation comments:

This is one of the very few science/engineering classes that are taught by female professors. I've been here at MIT for 4 years, and this class is the 2nd class I've had with female professors. I think it's super important to give a sense that women can do science and engineering too.

Research Videos showing the Faces of Chemistry at MIT

The *Why* and the *Who* of Chemistry

Do people actually use the stuff they learn in freshman chemistry?

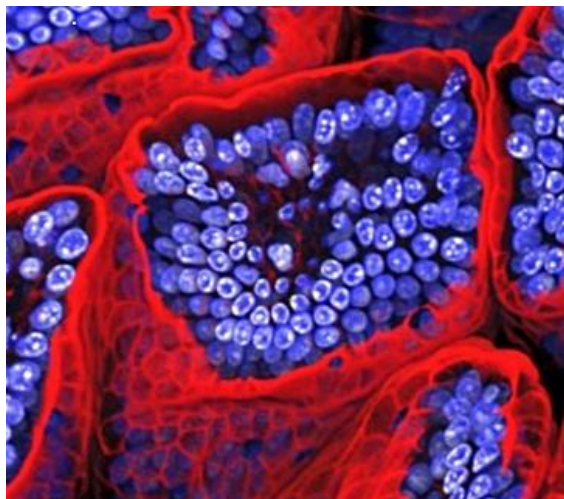
What do real chemists look like (apart from the dead white men in textbooks)?

Research Videos showing the Faces of Chemistry at MIT

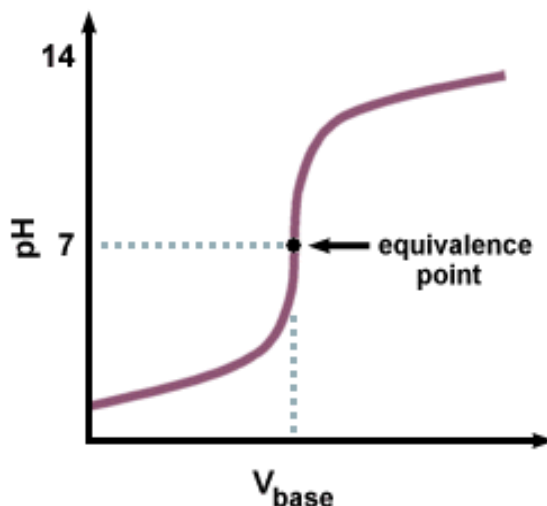
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What do real chemists look like (apart from the dead white men in textbooks)?



Application:
imaging diseased cells



General chemistry topic:
pH and pKa



MIT Researcher:
undergraduate
Sam Thompson

Samuel Thompson: MIT undergraduate in the Ting lab



Assessing impact: Faces of Chemistry videos

Assessing impact: Faces of Chemistry videos

From Spring 2011 Retrospective Survey (no videos yet!)

As a result of this class,	mean	% agree
I have been exposed to examples of chemists from different ethnic groups.	4.2	43%
I have been exposed to examples of women who are chemists (in addition to my professors and Tas)	5.4	81%
I encountered examples of chemists with whom I could identify because of their gender/ethnicity/background.	4.4	42%

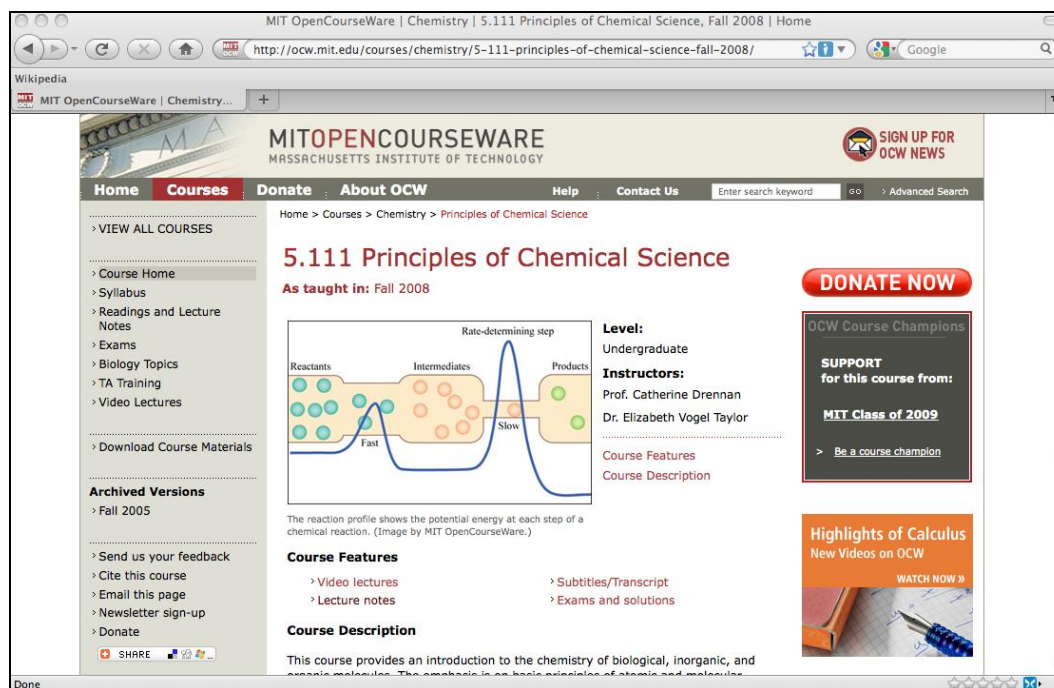
1.....4.....7		
poor/strongly disagree	neutral	excellent/strongly agree

Dissemination of resources: reaching teachers

MIT OpenCourseWare

Available materials: lecture notes, videos, transcripts, exams, etc.

Bio. examples highlighted, but not formatted for direct use by teachers



The screenshot shows the MIT OpenCourseWare website for Chemistry 5.111 Principles of Chemical Science, Fall 2008. The page includes a navigation menu with options like Home, Courses, Donate, About OCW, Help, and Contact Us. The main content area displays the course title, a 'DONATE NOW' button, and a reaction profile diagram. The diagram shows the potential energy at each step of a chemical reaction, with reactants, intermediates, and products, and a 'Rate-determining step' highlighted. The course is taught in Fall 2008 and is an undergraduate level course. The instructors are Prof. Catherine Drennan and Dr. Elizabeth Vogel Taylor. The course features video lectures, lecture notes, subtitles/transcripts, and exams and solutions. The course description states: 'This course provides an introduction to the chemistry of biological, inorganic, and organic molecules. The emphasis is on basic principles of atomic and molecular structure and bonding, and on the chemical reactions that occur in biological systems.'

5.111 is the 13 most-viewed course on OCW (out of 2,000 total)

- over 40,000 distinct page views per month
- over 6,000 downloads per month

Dissemination of resources: reaching teachers

OCW Secondary Education
Goal: provide TEACHING resources
(not just AP study resources for students)

The screenshot shows a web browser window displaying the MIT OpenCourseWare website. The browser's address bar shows the URL <http://ocw.mit.edu/high-school/for-teachers/>. The page header includes the MIT OpenCourseWare logo and navigation links for Home, MIT OpenCourseWare, Help, and Contact Us. A search bar is also present. The main content area is titled "For Teachers" and features a video player for "Highlights for High School Guided Tour 2009". To the left of the video player is a circular inset showing a preview of the video content. Below the video player is a "You Tube" logo. On the right side of the page, there are two promotional boxes: "OCW Course Champions" and "Highlights of Calculus". The "OCW Course Champions" box includes a grid of photos of people and the text "Support your favorite course or faculty member" and "Become an OCW Course Champion". The "Highlights of Calculus" box is orange and features the text "New Videos on OCW" and "Click to add your review."

Free Online MIT Course Materials for High School | For Teachers | MIT OpenCourseWare

Wikipedia

MIT OCW Free Online MIT Course Materials ...

MIT OPEN COURSEWARE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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Home > Highlights for High School > For Teachers Email this page

For Teachers

Our goal is to make it easy for you to find resources you can use to inspire your students.

Highlights for High School Guided Tour 2009

MIT OPEN COURSEWARE

MIT OpenCourseWare: Highlights for High School

Highlights materials for teachers.

For Teachers

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Highlights of Calculus

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Research Videos showing the Faces of Chemistry at MIT

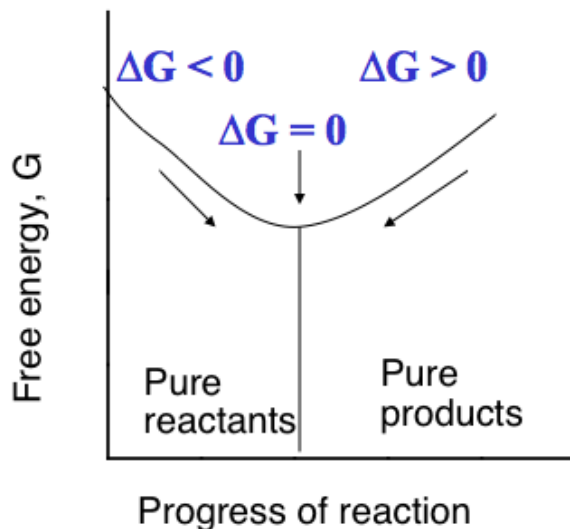
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Do people actually use the stuff they learn in freshman chemistry?

What do real chemists look like (apart from the dead white men in textbooks)?



Engineering microbes to remove greenhouse gasses



General chemistry topic:
Chemical Equilibrium



MIT Researcher:
Hector Hernandez

Hector Hernandez: MIT Postdoctoral Associate

Who is involved



Lourdes Aleman
Nazomi Ando
Sarah Bowman
John Essigman
Wes Glenn
Hector Hernandez

Meredith Knight
Jingnan Lu
Ben Ofori-Okai
Stefanie Sydlik
Sam Thompson
Darcy Wanger



Cathy Drennan



Rudy Mitchell



George Zaidan



Mary O'Reilly