CHEMISTRY CLASSES ARE TRANSFORMED

'Lectureless' classes, integrated curricula, lyrics, and movies help students learn and remember chemical reactions

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From the ACS meeting

True to form, the smorgasbord of poster sessions and symposia sponsored by the Division of Chemical Education turned up yet another bumper crop of innovative approaches aimed at engaging students in learning—and liking—chemistry.

In a variety of presentations, speakers told how students are singing their way to extra credit by composing lyrics that describe chemical reactions, learning thermodynamics in a discovery-based "lectureless" physical chemistry course, and interfacing chemistry and physiology by studying the biochemistry of poisons.

They described a program that optimizes students' comprehension of physical chemistry by dovetailing the sequence in which classes in math and physical science are taught, how the movie "Apollo 13" can be used to teach chemistry, and the impact on a rural viewing audience of "live" chemistry demonstrations on a morning TV talk show.

A sing-along depicting a variety of chemical reactions and their mechanisms enlivened the general poster session. To the tune of "America the Beautiful," "The Battle Hymn of the Republic," "The Hokey-Pokey," and "Oh My Darling Clementine," assistant chemistry professors Dee Ann Casteel and Gretchen M. Rehberg of Bucknell University, Lewisburg, Pa., led a chorus of spectators in songs that spilled the secrets of the Grignard and Wolff-Kishner reactions, among others. Their poster was appropriately entitled "Not the Same Old Song and Dance."

"We got a big hoot" from a song sent by a former student a few years ago, Casteel told C&EN. Subsequently, the two professors used the song in their freshman chemistry class as a teaching tool for organic chemistry. "Of course, the students thought we were ridiculous, but they learned it. They would sing the song and remember what is important" in a reaction. Now students are challenged to write songs about organic topics, and given extra credit if they do. "They really enjoy this," she said.

Meistersingers Casteel and Rehberg are compiling a library of songs from their three-year collection. "We're working on having songs for each reaction," Casteel said.

At another college in Pennsylvania—Franklin & Marshall College, Lancaster—a nontraditional approach to teaching thermodynamics made its debut last year. The lectureless course derived from earlier findings of the Division of Chemical Education Task Force on General Chemistry that educators need to accommodate different learning styles, said task force chairman James N. Spencer, a professor of chemistry at the college.

Photo by Pamela Zurer

Casteel: songs as teaching tools

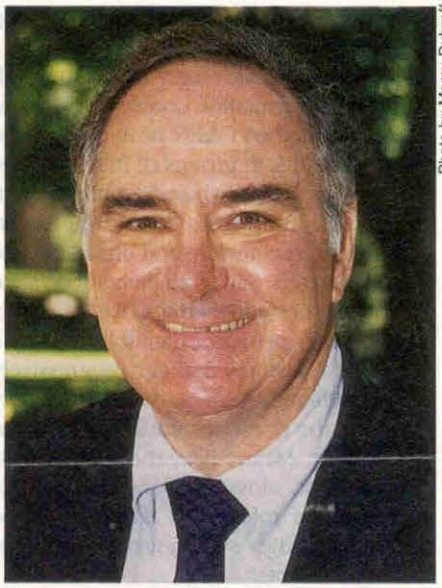

Photo by Marcy Dubroff

Spencer: active thinking in the classroom

In addressing a symposium called "Using Our Understanding of How Students Learn To Change the Way We Teach Physical Chemistry," Spencer described the different learning patterns among students and faculty. Many students prefer a concrete approach to learning, he said. Faculty members, on the other hand, and a small percentage of students, usually prefer an abstract, innovative approach. "Quite often there's a considerable mismatch in the classroom," he explained, "because the instructor is looking for one thing and the students for something else.

"We have learned that the way to create better matches between students and faculty is to use active modes of teaching and learning." Contrasting this "constructivist" approach to the traditional pedagogical approach, Spencer said that in the traditional approach, "a teacher feels that he or she can deliver an idea intact from his or her mind to the student—nothing interferes in between." But the constructivist approach assumes that students already have some relevant knowledge in their minds "and whatever [else] goes in must be assimilated with what's already there." Accordingly, "we think the students learn better when they are actively engaged in thinking in the classroom. They construct their own knowledge and draw conclusions by analyzing

data and discussing the ideas among themselves," he explained.

Chemistry major Larry Kim, who took the thermodynamics course last semester, explained to C&EN how it operates: Students work in groups of four, reminiscent of a discovery-based laboratory setting. Each group has a designated leader, note taker, technician, and observer. The teacher hands out worksheets that state a law in thermodynamics, for example, and contain pertinent data followed by a series of questions that get progressively more difficult. Students work their way through the questions until they arrive at an answer. Meanwhile, the teacher acts as a mentor, moving among groups. Students rotate roles on a daily basis, and every week they switch groups so everyone can interact.

"For some reason, the retention seems to be a little better" when one learns in this way, said Kim. "By figuring out things by yourself, [knowledge] just happens to stay with you better, I guess. . . . I enjoyed the class. It was a good experience."

At Dartmouth College, Hanover, N.H., faculty members in mathematics, chemistry, physics, and engineering have teamed up to design a program that coordinates their curricula, chemistry professor Joseph J. BelBruno told a symposium on integrated science and mathematics programs. BelBruno, who teaches physical chemistry, and a colleague in the physics department had observed that students in their classes had trouble recalling the calculus they had learned. In fact, "they would swear they had never seen this math before," said BelBruno.

The idea of finding a way to solve the problem took hold, and an interdisciplinary curriculum emerged for students who major in the physical sciences, applied mathematics, or engineering. Now students are learning mathematics in a sequence that enables them to apply their knowledge immediately in other courses. "The basis of the program is that mathematics is most effectively taught, retained, and made useful if presented within the context [of coursework] of immediate interest," explained BelBruno.

"We had some good models for designing the program from engineering schools and universities with large research divisions," he noted. "But we knew that introducing this kind of curriculum in a liberal arts environment would be a challenge."

Meanwhile, at the University of Nebraska, Omaha, students are connecting chemistry, biology, and physiology by learning how various poisons wreak their deleterious effects in the body.

At a general poster session, professor of chemistry Daniel M. Sullivan described how he interweaves the metabolism of various poisons in lectures on enzymology, acid-base balance, chelation, protein precipitation, bioenergetics, and a host of other topics so students can relate the class material to life around them. "This is

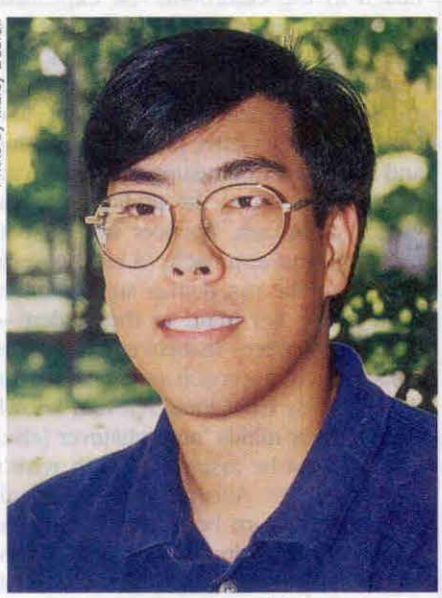

Photo by Marcy Dubroff

Kim: learning by figuring things out

Photo by Mitch Jacoby

Goll: a movie about testing hypotheses

PBS series on chemistry wins big in high schools

At the American Chemical Society's national meeting in Las Vegas, those attending the symposium on the use and misuse of chemistry in movies and on television learned about the impact of "The World of Chemistry," a 26-part television series that premiered in 1990 on Public Broadcasting Service stations.

Designed primarily as a telecourse and available on videocassette, the series has proven to be "immensely popular with high schools," said Donald L. Showalter, a professor of chemistry at the University of Wisconsin, Stevens Point. "It's also one of the fastest selling" products marketed by the Annenberg/CPB Project (a project of the Corporation for Public Broadcasting and the Annenberg School of Communications, which provided the major support for the series), he said. Roughly 60% of sales are to high schools, 12% to four-year colleges, and the rest are to government agencies, corporations, and individuals.

Showalter does the chemical demonstrations in the series; Nobel Laureate Roald Hoffmann, a professor of chemistry at Cornell University, is host. A typical half-hour segment takes a viewer from chemical theory to practice of chemistry. For example, said Showalter, a segment called "The Busy Electron" explains electrolysis and the electrolytic processes for making aluminum, then takes the viewer inside a production plant to see how aluminum is produced.

Annenberg/CPB Project

Showalter showing reactivity of potassium metal with water

"I visit a lot of high schools," said Showalter. "Recently, most of the invitations have been coming because they use the films. . . . I have stood for an hour and signed autographs—because I'm a chemist," and students are relating to the chemistry in the films.

The show has been broadcast in 24 countries and the U.S., and educators in several other countries have bought videocassettes. Now people are asking for additional topics, noted Showalter, including fuels of the future, nuclear chemistry, and materials science.

For information on the series, call toll free (800) LEARNER.

why chemistry and physics are so much fun to teach," said Sullivan, "because we have lots of good toys and interesting demonstrations" to invigorate courses.

"No discussion of bioenergetics is complete without considering cyanide ion, which stops the electron-transport chain dead," he said. While detailing the mechanism of biological electron transport, he notes that apple seeds and peach and apricot pits contain small amounts of cyanide and that recipes for folk medicines touted as cancer cures often list the pits as a source of a crucial ingredient. Such potions can be poisonous to babies or small individuals, he tells his students.

Household bleach, poisonous mushrooms, deadly nightshade (belladonna), heavy metals, narcotics, and anesthetics are among the several dozen "poisonous" materials Sullivan has added to his growing repertoire. Although not technically considered poisons, raw egg white, acetaminophen (the analgesic in headache remedies such as Tylenol), and vitamin A also are on his list.

Sullivan explained how a protein in raw egg white binds to a crucial carbon dioxide-carrying biological coenzyme, crippling its action. Although usually not fatal to humans, raw egg white can kill dogs that are fed it to make their coats glossy, he noted. By telling this story, he provides his students with a way to memorize and understand important cellular syntheses. Explaining the effect of too much acetaminophen or vitamin A involves a discussion of liver function.

But Sullivan has another motive for focusing on the biochemistry of poisons. "Common substances are much more toxic than the public generally believes," he says, "and practicing chemists are often called upon for information and should be informed."

Other innovative approaches to teaching chemistry were addressed in a symposium on the use and misuse of chemistry in the movies. James G. Goll, an assistant professor of chemistry at Glenville State College, Glenville, W.Va., described how he uses the movie "Apollo 13" as a teaching tool. (The 1995 movie is a re-creation of the ill-fated 1970 moon mission, when an oxygen tank exploded, leaving three astronauts facing dire consequences.)

Goll uses the movie to help students understand how a hypothesis is formed and to show applications of chemistry in space.

"The movie shows that initial hypotheses are not always correct, and highly trained professionals go through several hypotheses that are tested before a good theory is developed," he pointed out. Students follow the various hypotheses formulated by both the astronauts and their colleagues at the National Aeronautics & Space Administration's Mission Control Center in Houston.

Oxygen on the spacecraft was stored in its supercritical fluid state and needed to be stirred to keep it homogeneous. On this mission, the stirring resulted in a spark that ignited insulation. Once the fire started, the supercritical fluid began to expand into its gas phase. Goll draws his students into a discussion on gas laws and different states of matter.

Other chemistry "minilectures" bubble from the movie—the use of lithium hydroxide filters for removing carbon dioxide; the makeup of batteries and fuel cells that supply the spacecraft with energy; the reason the rocket fuel used for liftoff (kerosene-liquid oxygen) is different from the fuel (a mixture of hydrazine, dimethylhydrazine, and dinitrogen tetroxide) that powers the thrusters that maneuver the spacecraft. This leads to a discussion on the reactivity of the nitrogen-nitrogen-bonded compounds in the thruster fuel-oxidant system.

At the same symposium, William C. Deese, a professor of chemistry at Louisiana Tech University, Ruston, La., showed video clips of the chemistry demonstrations he carried out weekly for two years on an early-morning TV talk show broadcast from Monroe, La. The broadcast region covers rural areas in southeast Arkansas, northeast Louisiana, and northwest Mississippi.

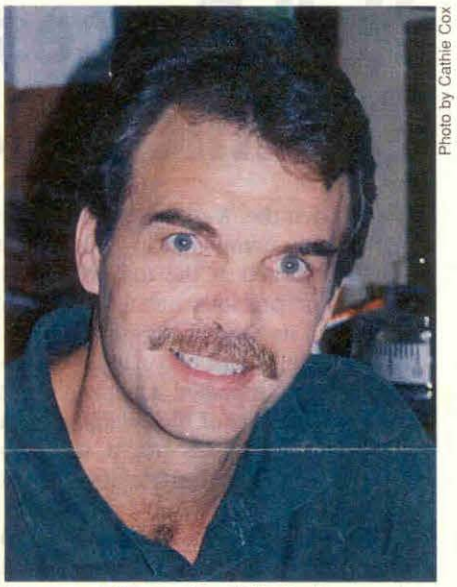

Photo by Cathie Cox

Deese: early-morning TV talk show

"It's amazing how [much] the general public is interested in things I do every day in the classroom," Deese said. Throughout the demonstrations, the show's cohost would engage Deese in an unscripted dialogue. "And that turned out to be pretty neat," he said. The show gathered an "eclectic" following, including public school teachers and children of all ages. In fact, children were asking their parents to wake them up to see it before they went to school.

Once a month for several months, Deese did a demonstration called "the science puzzler," which he invited viewers to solve. At the end of the month, all the correct answers were collected and a "prizewinner" was drawn. The puzzler became very popular—a lot of teachers would tape it to show to their classes, he said. "We would get big envelopes with 40 to 50 student responses in them." Some puzzlers drew several hundred responses, the majority of them coming from junior high and high school children.

Now the TV station has canceled the 6 AM show, and those chemistry demonstrations are off the air. While doing them, Deese says, "I always felt really good about stirring up that much interest in [chemistry] from the general public."

Despite this setback, the ACS meeting showed that many innovations are well received and are helping to make chemistry fun to learn and fun to teach.◀

Sing a song of chemistry

Students at Bucknell University, Lewisburg, Pa., are warbling their way through organic chemistry. Among the songs that help them understand and remember chemical reactions is

Oh Grignard, the Beautiful
(To the tune of "America the Beautiful")

The carbonyl is polarized
The carbon end is plus
A nucleophile will thus attack
The carbon nucleus
A Grignard yields an alcohol
Of types there are but three
It forms a bond to correspond
From C to shining C.
A secondary's synthesis
Requires an aldehyde
For tertiary, a carbanion
And ketone may collide
And Grignards add formaldehyde
The product's primary
They stick like glue to CO_2
Join C to lonely C.

A sampling of songs is posted on the Internet at http://www.bucknell.edu/~casteel/chem211/songs/