THE CHRONICLE
of Higher Education

Faculty

think

May 25, 2001

A Professor at Notre Dame Sparks a Quiet Revolution in How Chemistry Is Taught

By ANA MARIE COX

Dennis C. Jacobs had been teaching chemistry at the University of Notre Dame

---

ALSO SEE:

Cooperative Learning in General Chemistry, a Web site with materials related to the Notre Dame course

---

for almost 10 years before he set foot in front of a lecture hall full of freshmen in 1995. An active researcher with about half a million dollars in grants a year, he had dealt mainly with upperclassmen until he began teaching the college's general chemistry class, a survey course for freshmen that is a prerequisite for such science-related majors as engineering and pre-med.

"I saw teaching as part of my job and as rewarding. But the time I spent on it was nominal," he admits. Then Mr. Jacobs found himself

sitting across from a sobbing 18-year-old.

"She was facing dropping the course, facing leaving pre-med," he says. "She was terrified of what her parents were going to do -- 'Are they going to pull me out of the college?'"

Mr. Jacobs knew the stereotypical professor's response: The young woman's having to drop the course is a shame, but it's probably for the best. After all, gatekeeper courses like general chemistry are supposed to be difficult. But sitting in front of this student, Mr. Jacobs had a revelation. "Suddenly, I realized, this is so much more than a course for her. This affects her entire life -- all because she had six weeks of a mediocre learning experience."

"And," Mr. Jacobs thought, "it's my fault."

Spurred by a sense of responsibility he felt for the many similarly situated students, Mr. Jacobs went to his department chairman with a proposal. Within a year, he had designed Chemistry 113-114, an innovative, peer-led course aimed at students most likely to fail or drop out. Today, the retention rate in general chemistry for those students has increased by 55 percent, and their average grade-point average has gone up dramatically. In 1999, Mr. Jacobs was named a Carnegie Scholar by the Carnegie Foundation for the Advancement of Teaching for his work on peer-led curricula.

Lee S. Shulman, president of the Carnegie foundation, sees Mr.

Jacobs's success as part of a national trend that recasts the role of the introductory science course, broadening the gateway to certain careers that these courses represent.

Just last month, a panel on teaching organic chemistry at this year's American Chemical Society national meeting in San Diego drew attention to the issue. Teachers at institutions like the University of Colorado at Denver and the University of Missouri at Columbia spoke about revamping the notorious "orgo" with an eye toward inclusiveness and peer-led collaboration.

Says Mr. Shulman of this development: "You can think about gatekeeping classes as a filter, or you can think of them as an opportunity. What the gatekeepers are realizing is that they've done primarily only one of those and not the other." Mr. Jacobs sets an example, says Mr. Shulman, because "he saw a failure in his classroom not as vindication but a challenge."

At most other colleges and universities, the students that freshman counselors steer to courses like Chemistry 113-114 would not be considered "at risk." But at Notre Dame, where the average SAT score is 1350, Mr. Jacobs found that a student with a 630 or below on the math portion of the SAT had only a 40 percent chance of completing the traditional course (designated Chemistry 115-116 or 117-118) with a grade of C or above. By contrast, students who scored above 630 had a 75 percent chance of getting a C or better.

Mr. Jacobs's ability to keep those students enrolled in 113-114 and to push up their grades -- they are now twice as likely to get an A -- has garnered the attention of both the Carnegie Foundation for the Advancement of Teaching and his colleagues at Notre Dame, who have begun to pattern other science courses on the techniques Mr. Jacobs introduced to the campus.

The new class's content is the same as the traditional class's (it covers the same material at the same pace, and it fulfills the same requirements), but it adds an extra day of student-led tutorial sessions, required weekly homework, and a more interactive lecture. Because the administration approved Mr. Jacobs's course on the condition that he come back with evidence that his approach worked, the course also has mechanisms embedded in it to help him gather that evidence.

Mr. Jacobs collected data on about 4,000 students in the first four years of the course, and continues to track their success in future science courses as well as examine the connections between their high-school experience and their success in chemistry. This research has shown both the improved retention rate for general chemistry and an increase of 50 percent in the number of students who go on to complete the biology sequence following general chemistry, which is also required for pre-meds and other nonchemistry science majors.

This is no cult of personality: Mr. Jacobs stopped teaching the 113-114 course itself after the second year. Now other instructors use the template he created and continue to get the same promising results. Says Mr. Shulman of the Carnegie foundation, "It's not that he's the only scientist in the country that's trying do this sort of thing. The difference is that he's treating the process itself as science. You need to treat this an act of scholarship so that others can critique it and build on it."

As an undergraduate at the University of California at Irvine, Mr. Jacobs "went through all of general chemistry without taking a single page of notes. I would read the paper." He laughs, adding, "I felt very proud of that, because I wound up acing the course."

Mr. Jacobs allows this is probably how most science faculty handled their undergraduate education -- though perhaps with slightly more decorum. And that's exactly why the structure of science instruction hasn't changed all that much since Isaac Newton scratched formulas in front of students at Cambridge.

Walk into a Chemistry 113-114 lecture, however, and you are less likely to see a professor pontificating in front of the class than a class holding up a sea of paper arrows, as if they were cheering at a bowl game between acids and bases.

The arrows are an adaptation from interactive learning examples in Eric Mazur's Peer Instruction, and as cartoonish as they look, they

represent an object lesson for the sort of student enrolled in this class.

Asking students to generalize about whether, say, a certain reaction will result in a pH greater (up arrow), lesser (down arrow), or the same (sideways arrow) as the original solution breaks through what science educators derisively refer to as "plug and chug": the rote insertion of numbers into formulas without much attention paid to what the numbers mean or which formulas make sense. Joseph H. Bularzik, the class's current instructor, points out that as future engineers and doctors, "most of these people are not going to be doing exact chemical reactions later in life." One of the more significant achievements of 113-114, according to Mr. Bularzik, is to get students to stop thinking about what the "right" answer is and to start focusing on "What does this answer mean and why do I want it?"

Using Mr. Mazur's book as a starting point, Mr. Jacobs has found that forcing students to talk to one another about how a problem might be solved gets them thinking about concepts rather than answers. In lectures, students practice this sort of thinking whenever the instructor takes an arrow count, an approach suggested in Mazur's book. After the snap poll, the students are asked to turn to their neighbors and "defend their answer." Then the instructor takes another poll. More often than not, students who have grasped the concept in question have managed to convince

their neighbors, and the arrows point more uniformly toward -- well, sometimes it is important -- the right answer.

Using a group's combined knowledge to work out a problem is at the heart of Chemistry 113-114's most distinguishing characteristic, the peer-led tutorials.

Mr. Jacobs says that students do not enter the class with much confidence in this method: "Students don't think the students around them are good resources -- they're paying good money to be taught by a professional chemist."

Of course, letting the students figure out the answers runs counter to what the instructors are used to as well. The hardest thing to teach T.A.'s is restraint, says Mr. Jacobs: "Teaching them to respect the fact that students need space to make mistakes and recover from them."

But it pays off. Sarah E. West, a chemistry-department staff member who leads tutorials, says, "In the beginning, everything's new, they are afraid to make those guesses. Once they get to know everybody, they don't have the 'stupid' fear."

Maria Bea, a junior pre-med student who took the course her freshman year, says, "I remember being frustrated that they wouldn't help you at all." But, she says, it only seemed that way. She realized that not helping -- that is, not providing the answers -- was

the best kind of help to have. Because that approach forced her and her classmates to discuss the problem, with one another and the T.A. In the end, they learned more than just the answer.

Explains Adam Tibble, another veteran of the course and a junior: "In other courses, your only T.A. is your lab T.A., and you don't talk to them and they don't do jack." He adds, somewhat embarrassed, that he had assumed all the extra sessions and more attention from T.A.'s would mean that Chemistry 113-114 would be a smoother ride past the pre-med prerequisites. "I personally saw the lower number and thought it would be easier," Mr. Tibble admits. "It wasn't."

The clearest sense of the class's potential comes from observing the students at work. For one thing, late in the school year, when spring's siren call drowns out many lectures, students actually go to class. Sean B. Seymore, a former T.A. who received his Ph.D. this spring, says that "students in the other course are usually miserable, bored, they stop going to class. In 113, they're still excited, they're having fun."

During one of the 113-114 tutorials, Mr. Bularzik tells a stymied group, "You know what to do at this point. You vote and decide if that's the right answer." The students sigh exaggeratedly and one riffs on Survivor: "OK -- tribal council."

But the ruthless competitiveness of reality television shows is the furthest thing from the reality of the class, which is intentionally

collaborative.

Mr. Jacobs didn't know it when he started to develop this new class, but this atmosphere of collaboration and the specific changes he made to the traditional curriculum reflect a growing desire among science educators to shift away from their role as gatekeepers.

In addition to the pedagogical research and curriculum studies generated by the Carnegie Foundation for the Advancement of Teaching, the National Science Foundation oversees five large projects and 11 smaller ones that aim to overhaul chemistry instruction, many of which focus on the potential of peer-led teaching. Susan Hickson, of the N.S.F., says that one aim of their programs is to get beyond traditional measures of student success. "A lot of students are struggling with how to measure if students have a deeper understanding of the material."

At the A.C.S. panel on organic chemistry, Jack A. Kampmeier of the University of Rochester talked about using a peer-led approach similar to Mr. Jacobs's. In the past few years, that approach has raised the percentage of students at Rochester who get a C or better from 67, in the mid-1990's, to around 80 percent today. One organic-chemistry course at Princeton University has taken the peer-led approach to an extreme, eliminating lectures almost entirely in favor of small group work.

Slowly, courses that were once thought of as gatekeepers --

intentionally difficult classes that prevented all but the most prepared from succeeding -- are becoming training grounds.

"General chemistry, organic chemistry," says A. Graham Lappin, the chair of the Notre Dame chemistry department, "have been gatekeepers and we recognize that." But Mr. Lappin says that Mr. Jacobs's success has prompted the department to take into account the wide range of preparedness -- both academic and emotional -- that students bring to college. "One of the things we've tried to do," he says, "is to make sure that general chemistry and the process of settling in away from home are not the sole determinates of a career path." By giving students a greater chance at completing general chemistry, Mr. Lappin notes, they are giving students greater options, including, he says, the opportunity to "realize more of their dreams."

---

http://chronicle.com Section: The Faculty Page: A12

Notre Dame Cathedral was hit by a massive inferno, that destroyed part of the iconic buildingCredit: EPA. What started the Notre Dame fire? Fifty investigators have been assigned to probe the origin of the fire which ravaged the Notre Dame Cathedral in Paris on April 15. An electrical short-circuit was the most likely cause of the Notre Dame cathedral fire, investigators believe. Detectives have begun interviewing the specialist restorers who were carrying out work on the church's spire. More details have emerged since hundreds of firefighters tackled the historic blaze, battling to stop