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Award Address

Using the Arts To Make Chemistry Accessible to Everybody

2002 James Flack Norris Award, sponsored by ACS Northeast Section[1]

by Zafra M. Lerman

Although all chemists know the importance of chemistry in daily life, the rest of the population somehow does not seem to share our view. Each of us believes that we must teach chemistry to everyone, yet we have not succeeded in persuading everyone that they must study chemistry. I believe the reason is often the methods used to communicate chemistry to the public. The arts (music, dance, drama, fine arts) are excellent vehicles to enhance understanding. For example, most people are not interested in the concept of the ionic bond, but when presented as a love story between Sodium and Chlorine like Shakespeare's Romeo and Juliet, people enjoy learning about the bonding relationship. In addition, the drama students who write and act out the script remember the concept far longer than would be expected through more conventional teaching methods. The same is true for students who wrote and acted in "The Bondfather", and for the students who danced "The Three States of Matter". (Our hero falls in love with Solid, but "When she warms to him, through his fingers she runs" and when his love heats up with Liquid, "Her love escaped from him just like a vapor".)

The Beginning

My story of using the arts to make chemistry accessible to everybody must begin with how I came to Columbia College Chicago. My research career in secondary isotope effects included time spent at the Weizmann Institute of Science, the Technion–Israel Institute of Technology, Cornell University, Northwestern University, and E.T.H.–Swiss Polytechnicum. The modern Columbia College was started in the 1960s by then-president Mirron (Mike) Alexandroff with 200 students. Mike used to say it was "a school that no parent heard about, but every child on the street knew about". He was very liberal and attracted former members of the Progressive Party of the 1940s as instructors to the school. His vision was to start a school that would be a model for the future, with an open admission policy to allow everyone to have a chance in life. Columbia is not an open graduation school, but with its open admission policy, any student with a high school diploma can attend. Mike wanted to make Columbia College a place that would attract students from the inner city, students who would otherwise never have been able to go to any other art school simply because they would not have the established portfolio required for admission. Mike surrounded himself with the best and the brightest of the city of Chicago to teach. They did not always receive a salary, and sometimes they even had to contribute their own money to help the school survive. Today the school has more than ten thousand students—it is the largest art school in the country and the largest independent college in the state of Illinois outside of the comprehensive universities. When Mike started Columbia College, it consisted of one floor in a rented building; today we own fourteen buildings, and Columbia is the largest landlord in the South "Loop" area. Chicago is our campus—and it is a big one! We have students from all over the world, but the original philosophy and vision remain intact.

Columbia College was accredited as a liberal arts college in 1974. After a few years, Mike decided that, as a liberal arts school, science had to be added as a component of the curriculum. But how to do it was a big concern, because it meant suddenly bringing science into a place packed with so many creative artists, writers, dancers, actors, musicians, and poets. He sent a letter around the country searching for a scientist involved in arms control and disarmament, in human rights, in helping minorities, and in caring for the poor. A good friend of Mike's was the editor of *The Bulletin of Atomic Scientists,* and distributed his letter among scientists who were active in the Pugwash Conferences and who regularly read *The Bulletin of Atomic Scientists.* My name came up, and Mike invited me to the college.

The Year Was 1977

When I arrived at Columbia College, I was dressed for an interview. I had an appointment with the dean, so I waited, and waited, and waited. In the meantime, a very thin and gaunt man, who had long hair down to his waist and a goatee, walked by—I was sure that it was Jesus who had stepped directly out of Da Vinci's "The Last Supper" (he turned out to be the Executive Vice President). Following him was a beautiful large man, with long flowing white hair, a long white beard, and bushy white eyebrows. He was so impressive that if I had to draw Moses, this is the only image I would have chosen (this man was the college's President). I said to myself: "This must be quite an interesting place, where Moses and Jesus walk together." While I continued to wait for the dean, the secretary kept assuring me that he would be there soon. Suddenly, the door opened, revealing a person with long brown hair, wearing glasses with pink lenses, an embroidered purple shirt, and a ring on every finger. This image asked "Can I help you?" and I responded: "I am waiting for the dean." He answered: "I am the dean," and the only reply I could think of was "Oh." He invited me to his office and reminded me that I had never sent him my résumé. I told him that I brought it with me, and put it on his desk. He then proceeded to apologize for his tardiness, explaining "I am late because the faculty and administration went for a retreat this weekend." I was in a state of shock because, until that time I knew only about Baptists and Hari Krishna going for retreats, but I had never heard about university faculty and administration going on retreats—I was sure I was

Award Address

in a cult and this place had nothing to do with an academic institution. But, this was the 1970s, and I listened carefully to his story about the retreat. When he finished, he asked me a few questions and finally said: "We will be in touch with you." I said "Goodbye," and picked up my resume. He said "We need your resume," and I replied "To be honest with you, I cannot allow my résumé to be left here." The end of the story is that I joined the cult and, in 1977 started a long, long love affair with Columbia College.

The First Class

The first class that I offered was called Chemistry in Daily Life. When this class appeared on the students' registration forms, it was erased by faculty members from their major departments, who told them: "Why do you need to know chemistry? I never took chemistry, why should you take it?" After a few days of registration, I realized that I would not have a paycheck if nobody was in my class, and that I had to invent a way to get some students.

I decided to bribe a group of students into taking my class by inviting them across the street to a very nice bar. As you might know, I am an Israeli and, at that time, Israel did not have a legal drinking age. I was unfamiliar with the restriction in the U.S. (Had I known about it, I probably would have ignored it, so it did not matter anyhow.) I offered to buy the students a round of drinks, so they joined me at the bar. They ordered their drinks and I started hearing terms like Bloody Mary, Screwdriver, Black Russian, Green Grasshopper, and Pink Lady. I thought, "My God, I was sure I understood English, but I don't understand one word of what they are saying," and asked for explanations. They responded: "Oh, this is orange juice and alcohol", and "This is tomato juice and alcohol", etc. An inspiration came to me, and I asked, "What is alcohol?" There was silence. Then someone said, "Alcohol is something that makes you feel good." I then inquired, "Yes, but what *is* it?" and no one could answer me. I then proceeded to explain to them the chemistry of alcohol. In a short while the structure of ethanol had been drawn on everyone's paper napkin. After a while, the entire bar was participating in the discussion and I became so drunk with success—not with alcohol—that I decided to continue. For a little more money, I ordered salad with oil and vinegar for everybody. When the salads arrived and everyone started eating, I asked: "What is vinegar?" Again, no one knew. I told them that it is acetic acid, and pretty soon everyone in the bar had the structure of acetic acid drawn on a paper napkin. At that stage I told them that ethanol and acetic acid can react with each other to form an ester, and this ester is sometimes used as nail polish remover. Everyone in the bar was shocked and frightened, believing that they had nail polish remover in their stomachs. I had to calm them down by explaining that this reaction required a catalyst, and explained what catalysts are. After three or four hours had passed, I made the announcement: "To the ones who will register for my Chemistry in Daily Life class, the semester is 15 weeks long and, after today's session, you only have 14 weeks left." This is how I got my first class. I had no need to bribe students after that because by word of mouth students learned that my Chemistry in Daily Life class was one of the most interesting classes at Columbia College *(1)*.

Figure 1: An illustration of what is *not* practiced in the Science Institute: "Chalk and Talk." *(Art by Joe Nelson)*

This experience taught me a valuable lesson about teaching chemistry: If you make chemistry relevant to the student's life, experience, environment, and interests, you can teach them anything you want, even secondary isotope effects. I learned that you have to adjust the methods of teaching to students' different styles of learning *(2)*.

In 1977, it was unusual to make chemistry relevant to students' lives, relevant to the environment, and relevant to students' interests. Many chemists were suspicious that I was sacrificing the chemistry in order to attract the students by using these methods. In the 1980s and 1990s teaching chemistry in a relevant way became the rule, and was no longer the exception.

An art student decided to emphasize in a poster that this chemistry class, with the lively discussions and active student participation, was quite different from the "Chalk and Talk" classes he had experienced before. His illustration can be seen in Figure 1.

Saturation

In the first class, I told my students that because they were not used to taking science classes, they would not have to wait for a break if they felt saturated with the material. All they needed to do was hold up a sign that read SATURATED, and I would shut up and take a break. To explain fully what I meant, I had my students conduct their first hands-on experiment to explore the phenomenon of saturation. They were provided with beakers of water, and were asked to slowly add sugar to the water, while stirring the solution. The students observed that the sugar dissolved. I explained that this is similar to their ability to absorb the material I was teaching. The students were then asked to continue adding sugar and report their observations. After a short while, they all observed that the sugar no longer dissolved, and the excess settled to the bottom of the beaker. I explained that the solution had reached what chemists call the "saturation point". Refer-

Award Address

Figure 2. Young dancers representing chemical concepts visually during a Gordon Research Conference. *(Choreographed by Heidi Bauman Renteria; photograph by David Morton)*

ring to our original analogy, I asked "So, when you are saturated with what I am teaching, does it make sense for me to continue?" They all agreed it did not, and I announced that this is the point when they are allowed to hold up a sign saying SATURATED, and we will take a break. The students next put their beakers on hot plates, and continued to stir the solution. They observed that when the temperature was raised, the excess sugar dissolved so they could add and dissolve additional sugar. I then asked, if they raise a SATURATED sign, will it help them absorb more material if I raise the temperature in the room? Their immediate reaction was laughter, as all agreed that the result would be that they would all fall asleep. I explained to them that this is the point where the analogy ends between the hands-on activity and their ability to absorb information. We continued the activity. The students allowed the super-saturated solutions to cool with a weighted string suspended in the solution. By the next class session, the excess sugar had crystallized, and the students had "rock candy" *(3)*. This permitted further discussion on crystals and recrystallization. Because Columbia College is an art school, the students were provided with food coloring to add to their solutions, which made the experiment more aesthetically pleasing. The astonishing fact is that my students seldom raised SATURATED signs and did not abuse this privilege and power.

In the workshops we run in the Institute for Science Education and Science Communication (Science Institute)[2] for Chicago public school teachers (funded by the National Science Foundation, NSF), we begin with this same saturation activity and explanation. The teachers love this experiment, and report that they repeat it with their own students, who find it fascinating.

Science in the Media

To show students the importance of having some background in chemistry to be effective citizens in a democracy,

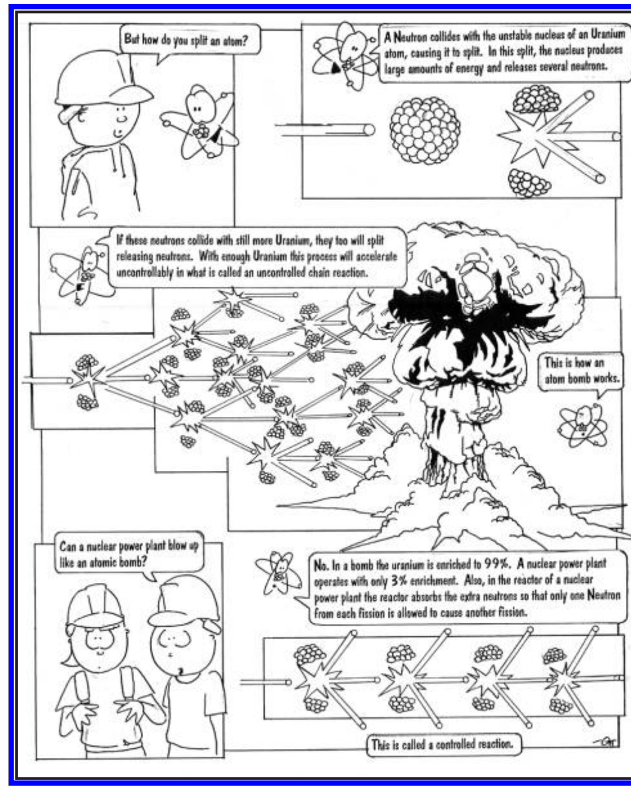

Figure 3. A cartoon depicting the fission reaction. *(Art by Michael Ossian)*

I ask each of them to bring to each class a newspaper article related to energy, environment, chemicals, and so forth, and to give a brief summary *(4)*. This exercise makes it clear that a science background is needed to really understand even the simplest article dealing with scientific phenomena in a daily newspaper. It shows students that science is part of everyday life. It demonstrates how important it is to communicate science correctly, and it develops the habit of looking for science articles in magazines and daily newspapers. I always try to find a way to relate a day's topic back to the articles students presented at the beginning of class, to add a deeper perception of daily life relevance to the course material.

Projects as an Alternative Assessment Method

Different methods of teaching must be accompanied by different methods of assessing students *(5)*. I had to develop alternative assessment methods in order to adjust to different teaching and learning styles.

When I was a student, from first grade through my Ph.D., I hated written tests. I resented that in the course of one hour, no matter how I felt, I had to be brilliant to show that I really deserved an A; I promised myself that if I were ever to teach, I would not do this to my students. I often carry with me a story about a very famous Rabbi named Hillel. The story says that a man approached Rabbi Hillel and asked him: "Can you teach me the whole Torah while I

Award Address

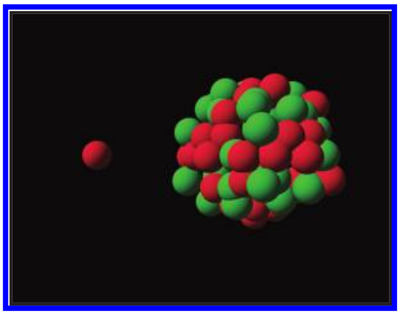

Figure 4. Computer graphics visualization of a neutron bombarding a nucleus. *(Graphics by Todd Ripplinger)*

Figure 5. Visualization through dance of a neutron bombarding a nucleus. *(Choreographed by Heidi Bauman Renteria)*

stand on one foot?" The old distinguished Rabbi answered: "What is hateful to you, do not do unto your friend. That is the whole Torah, the rest is commentary. Now, go and learn." Following Rabbi Hillel's advice, and always considering my students to be my friends, I will *not* do to them what I hated being done to me. Therefore, my students can show me their knowledge any way they want—by using the tools of their majors, their personal interests, their hobbies, their cultural backgrounds, etc. Students show their knowledge using the media with which they feel most comfortable. A benefit of this method is that not only the instructor but the entire class participates in the evaluation process. Students spend long hours preparing their projects; they learn much more by producing these projects, they retain the material much longer *(6)*, and they have a very positive and enjoyable scientific experience *(7)*. Student projects have taken a wide variety of forms, including dance and musical performances, paintings, sculptures, drawings, short films, theatrical skits, photo essays, and videotaped presentations. Many students have later presented these projects in job interviews.

It is significant that this positive experience with chemistry has motivated students to choose careers in chemistry or chemistry-related fields after graduation. One of my former students is now in the final stages of a Ph.D. in organic chemistry, while another recently received a Ph.D. in molecular biology.

These methods of teaching and assessing science were extended over the past 12 years to the Chicago Public Schools, and many inner-city students are now pursuing careers in chemistry and chemistry-related fields. As one teacher has testified: "I believe Zafra's greatest success can be seen in my own students' enthusiasm and new interest in science. Many have gone on to careers in chemistry, chemical engineering, medicine, and pharmacology. I sincerely doubt that any of these African-American students would be on these career tracks if it were not for my own experience with Zafra Lerman and her continuous mentoring."

These methods are also used to teach chemistry in a very non-traditional and informal setting: at night in a dance studio. Four hundred children from low-income families and homeless families gather in a dance studio where one of Columbia College's former dance students teaches dance and I teach chemistry. Twenty of these students (ages 12–16) accompanied me to the 2001 Gordon Research Conference on Science Visualization and Education.[3] These young dancers visualized scientific concepts for the audience through dance, and received a standing ovation from the international group of scientists *(8)* (Figure 2). This program, Feet-On Science, has been in existence for 12 years; this year, one of the former female dancers entered a Ph.D. program in biochemistry. In a television interview ten years ago, this girl stated "This program has helped me decide on a career for myself; and the career which I would like to go into is: I want to be a biochemist." *(9)*.

Examples of Projects

I typically try to provide a historical background on scientific discoveries when teaching a scientific concept, so when we begin the classroom discussion on fission, I mention the first fission reaction performed by Otto Hahn and Fritz Strassman in 1939 in Germany. I then ask the students if the year 1939 in Germany has any significance. This brings us to a discussion concerning World War II, and the students understand different scientific developments in the context of history and geography.

An art student created a cartoon book for children on the subject of fission and the atom bomb; the cartoon is written in a way that the atom is a child who describes to the other children what happens to him when he is being split during the fission reaction (Figure 3). Another book on this same subject was created by a group of art students, with each student creating a separate page of the story, using a different art style.

A television student visualized the same concept in an animated video titled *Little Boy.* Figure 4 shows the computer animation from this project demonstrating the bombardment of a nucleus by a neutron. In Figure 5, exactly the same concept is shown through dance: a neutron (seen in mid-air flight) bombards a nucleus.

The concept of the ionic bond is a very popular concept for these creative students to visualize in different formats. One art student represented this concept visually as a nine-page comic book super-hero story; four of these illustrations are shown in Figure 6.

Figure 6. "Ionic Bondage", depiction of the ionic bond. *(Art by Joe Nelson)*

Transfer of Methods

In order to demonstrate the scientific rigor of the chemistry class, I decided to take advantage of the common perception that if something involved Harvard, Yale, or Princeton, then it must be good. Over the past 17 years, I have chaired the Subcommittee on Scientific Freedom and Human Rights of the International Activities Committee of the American Chemical Society. The original members of the Subcommittee were Tom Spiro (Princeton University) and Jack Shiner (Indiana University). I shared with them my tenet that "equal access to science education is a human right that belongs to all" and, therefore, equal access to science education should become the concern of the Subcommittee. I proposed we develop together a class that we could offer in the three very different institutions: Columbia College (an inner-city, open-admissions art school), Indiana University (a big state school), and Princeton University (a very admission-selective private school). The idea behind this collaboration was that the three institutions cover much of the spectrum of U.S. institutions of higher education, and thus a course developed and offered by this collaboration could be adopted by other institutions *(10)*. We titled the course From Ozone to Oil Spills: Chemistry, the Environment, and You. We developed the course with support from NSF, which referred to it as their flagship project. However, to prove that my students covered the same material as Princeton students, every year for the past 10 years I have flown a group of my students to Princeton where we hold joint student symposia. The students from both institutions present their projects and ask questions of each other. By the end of the day the two groups become one; they exchange information, make valuable contacts, and promise to keep in touch with each other.

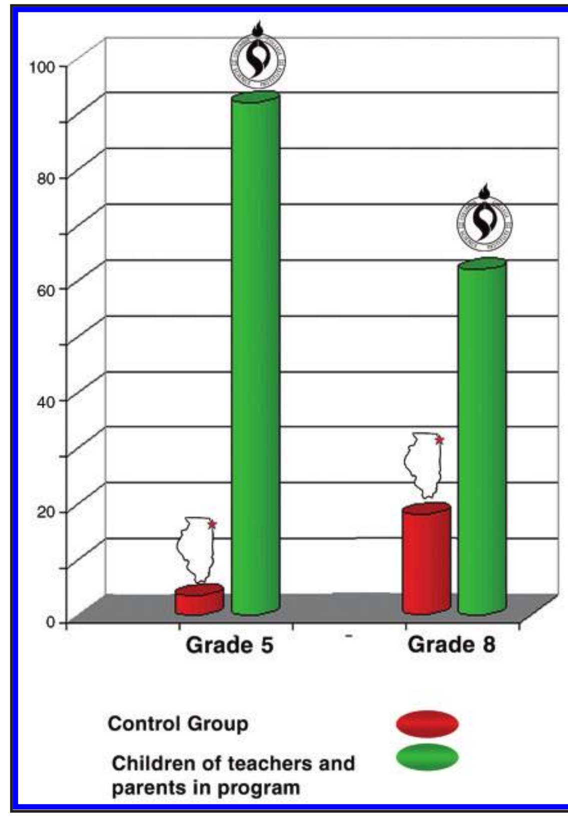

Figure 7. Comparison of fifth and eighth grade student achievement of teachers who participated in Science Institute teacher workshops (represented by Science Institute logo), with students whose teachers did not participate in the workshops (control group, represented by a map of Illinois). *(Statistical information by Jon Miller)*

As mentioned above, we work very closely with Chicago Public Schools and offer teacher workshops funded by NSF. For all our projects, the Science Institute utilizes an outside evaluator to compare project results to national standards. Results from these evaluations show how children of teachers who participate in our programs fare against those of teachers who did not participate. The crucial year is fifth grade (immediately before entering U.S. middle school); Figure 7 shows that our project benefited children of this grade resulting in scores more than 10 times higher than the control group. Another crucial year is eighth grade, before children enter U.S. high school *(5)*.

Dissemination of Methods

These methods have helped in the public understanding of chemistry through many formats. Both the electronic and print media in the U.S. and abroad have reported extensively on this approach of teaching, learning, and assess-

Award Address

ing science. On many occasions, these reports have featured examples of projects and interviews with students. For example, The Honorable Richard Riley, Secretary of Education during the Clinton administration, requested a video that would show examples of projects created by Columbia College students, Chicago Public School teachers, and Chicago Public School students. This footage was shown when he addressed the public in a satellite town meeting aired on public television through PBS, and viewed by an estimated 20 million people. This was a great compliment and acknowledgment to have a Secretary of Education address the public on the importance of using the arts to teach science, and using the Science Institute's projects as a creative and innovative way to accomplish this.

Acknowledgments

I thank all the students at Columbia College Chicago who attended my classes since 1977, who inspired me to forget the traditional methods of teaching and develop creative methods of teaching, learning, and assessing science. I could never have done what I did in any other place in the world. So to all my students, wherever you are: Thank you.

Thanks also to my students for the illustrations that appear in this paper. Everything seen was created and produced by them, as there is no better way of learning than by doing.

Thanks to NSF for support of this work through grants ESI-9619141; ESI-9253266; USE-9150524; and TPE-8955128. Thanks to WPWR-TV Channel 50 Foundation for support in taking dancers to the 2001 Gordon Research Conference on Science Visualization and Education.

Notes

1. This paper is derived from a talk given at the presentation of the James Flack Norris Award for Outstanding Achievement in the Teaching of Chemistry of the Northeastern Section of the American Chemical Society, held November 7, 2002.

2. The Institute for Science Education and Science Communication (Science Institute) was established at Columbia College Chicago by its president Mirron Alexandroff to design new initiatives in science and public policy, science communication, and science education.

3. The 2001 Gordon Research Conference on Science Visualization and Education was held at Mount Holyoke College. The students accompanied me at the invitation of Loretta Jones, the conference chair, and with the financial support of the WPWR-TV Channel 50 Foundation.

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