

Quotes

Workshop 1. Atoms and Molecules

Scientists and Experts

Brian Smith—Chemical structure of nanotubes—Unit 1.1

“This is a single nanotube which has been filled with C_{60} molecules. They are actually moving back and forth inside the tube. That happens spontaneously while we’re imaging them.... There are a lot of things that we can potentially put inside nanotubes. Molecules that are bioactive...for chemotherapy targeted at the sub-cellular scale...new types of electronic materials...building very stiff materials....”

Prof. Jack Fischer—Technological applications of nanotubes—Unit 1.1

“One of the first really big excitements about what these might be good for, had nothing to do with large scale materials or large scale synthesis. It was based on the idea that if you visualize an individual tube as being made by just taking an individual graphite layer of chicken-wire and rolling it up, what you get for a nanotube depends on how you do the cutting of the little rectangle that eventually is going to be rolled up into a tube....”

Dr. Brett Dunlap—Technological applications of nanotubes—Unit 1.1

“...Because one has a form of carbon that is both an insulator and a semi-conductor, and can be a perfect metal, one can start thinking about making computer parts out of metal tube segments....”

Prof. Roy Tasker—The modern atomic theory—Unit 1.2

“The modern theory of the atom, developed in the 1930s with the quantum mechanical model, which describes mathematically how electrons have both particle-like and wave-like character, hasn’t changed since then and is the best one we’ve got.... The analogy I use often is propeller blades moving quickly...the nucleus, of course, is extremely small, and we will not be able to see it anyway, but just as we know that the blades are there, when the blades are moving around, you get a perception of a smudged, cloudy look. That’s not a bad analogy to the way electrons are arranged in an atom....”

Prof. Darleane Hoffman—The periodic table—Unit 1.3

“The periodic table, for me, is the roadmap to chemistry; where to look and what to expect. It’s probably the most fundamental thing in all of chemistry because these are the elements which make up all the world around us and the whole universe, and nothing could be more fundamental than studies of the elements.”

Prof. Darleane Hoffman—Elements 99, 100—Unit 1.3

“Some elements were discovered totally unexpectedly. Elements 99 and 100 were discovered in the first U.S. thermo nuclear test, which was conducted in the South Pacific. These two elements were discovered in the debris from that test, which were collected later on...anytime you discover a new element or new isotope, it’s a real high, when you’re sure that it is true and that you’ve pinned it down, because you’ve seen something that nobody has seen before....”

Prof. Hugh Salzberg—History of the atomic theory—Unit 1.5

“[Democritus:] Everything was composed of atoms, which moved randomly in a vacuum, in a void. They collided into each other by chance. This was the absolute negation of Aristotle’s idea that everything had a purpose as divinely ordained [the theory of the Four Elements].”

Quotes, cont'd.

Dr. Willie May—About the mole—Unit 1.6

"The primary unit for the amount of substance in a chemical element is the mole, and if you are talking about the stoichiometry of a reaction, the mole is the basis for that."

Prof. Roy Tasker—About atoms and molecules—Unit 1.7

"Atoms really are not the central thing in chemistry at all because they are like the Lego blocks that are used to build things; the molecules are much more interesting, they're combinations of atoms together. And then of course what people don't realize is that when you take two atoms together and form a molecule or some other substance, that other substance is completely different from the character of the separate atoms.... Hydrogen atoms are extremely reactive, oxygen atoms are very reactive. If you combine them together, you get H₂O, which is some non-reactive substance...but if you get hydrogen peroxide...that's a very reactive molecule...."

Prof. Darleane Hoffman—Teaching chemistry—Unit 1.7

"...If I were teaching...I would first try to give them the fundamentals, of why that's important, why we're interested in the Periodic Table, why we're interested in radiation, where all our elements come from, it's really exciting—how this came to be, and what processes are involved."

Dr. Laurie Geller—Chemistry in everyday life—Unit 1.7

"So often when you're learning chemistry, it seems that you are learning laws and rules that don't have much application in real life. All you have to do is look around and you will see that chemistry is basically everywhere. That table in front of us is made up from a collection of atoms; it's important to understand how they are arranged and how bonds and energy hold them together. The air we are breathing is composed of a very specific mixture of atoms and molecules. And pretty much, everything we encounter in daily life rests on chemistry."

Students' Ideas

What Is an Atom?—Unit 1.2

"I think an atom is something really, really small, about...mmm...this big...."

"An atom is a particle of mass; it's really small and this is about all I know...."

"I think an atom is a little thing; it's got neutrons and protons in the middle, in the nucleus, and then around it...it has got electrons, and it's in everything...."

"I think an atom is the building block of everything. Its nucleus is made from protons and neutrons and it's surrounded by electrons in orbit...."

What Is a Mole?—Unit 1.6

"The mole is like, that every person has got one mole or whatnot...."

"I think this is the 6.02×10^{23} thing...."

"Something that hunches underground—an animal—and it digs...."

"It's used for calculating lots of chemistry equations...."

Teachers' Forum

Models for Visualization—Unit 1.2

Gannon Sugimura—"When I start the year in chemistry, one thing I do is write the words for chemistry in Japanese on the board. What it means in Japanese is to study changes, and that really helps me to get across the study that accompanies change: Atoms to molecules, different states of matter, and such."

Dr. Michael Clarke—"I use jewelry to introduce the difference between an element and a compound, because it's something that everybody is familiar with, especially gold. And talking about purity and impurities in gold jewelry and how that relates to quadrates...and I can get my kids to participate in that."

Caryn Galatis—"One of our biggest problems is that 90% of what they see is not really on the level of what they're expected to know. You see the color change, you see it happening, but they have to understand it on the level of atoms and molecules.... It's something that they are never ever going to see, so we've gone to something that they can physically manipulate on the table..."

Catherine Del Conte—"Since our school team is called the Annandale Atoms, we have a really weird-looking atom symbol. Basically, I take this symbol, bring it into class, and have them tear it apart and tell me what's wrong; this is not what we've been taught that an atom looks like, because this is an image from 1955 when our school was built; they thought the atom looked like that and it's wrong!"

Tom Pratuch—"Worse than that, it has taken us three years to find out that that drove all the understandings that were going on and it took what we went through to make students draw things. What we found out was that their understanding of the atoms stylizes three elongated orbitals, ...which represents the three parts of the atom: the neutron went on one, the proton went on the other, the electron went on the third...when we discovered that we suddenly understood why they were performing all of the reactions and calculations wrong. It took us three years to come out with a program to eliminate that..."

Modeling Atoms—Unit 1.4

Caryn Galatis—"We're going to experiment with isotopes next semester. It's always been such a huge problem, the parts of the atom, and having them get that straight. Leslie came up with this idea. We went out and bought a whole bunch of poker chips. They're going to make atoms from poker chips."

Dr. Leslie Pierce—"We're going to have protons, neutrons and electrons, and we're going to write the pluses, the minuses, and the zeroes on the poker chips, and just move them. We thought we could use the poker chips to model nuclear reactions and isotope reactions."

Catherine Del Conte—"One of the things that really helps when you do this is a really neat board-type thing that uses marbles, with different sizes of marbles, to be able to determine the neutrons, electrons and protons."

How To Teach New Concepts—Unit 1.7

Sharon Walton—"Many times I try to figure out what they already know about the topic, and if I can find any fact to start with, which they've learned in a previous grade, I work and expand from there, and let them know where we are going. Something they've learned in biology or in another course or everyday life, and then go on from there..."

People Learn Differently—Unit 1.7

Irene Walsh—"One of the most important things that a chemistry teacher has to be aware of is learning students' patterns, the fact that people learn in different ways, and try to make the subject approachable to students. What is logical to us might not be logical to them and that's where you need to start looking out for ways to make things more concrete for them and build the abstract from that."

Workshop 2. Macro to Micro Structures

Scientists and Experts

Brian Smith—Discovery of C₆₀ inside nanotubes—Unit 2.1

"I can remember the day when I got the first image. I almost fell in my chair. It was very exciting...we initially saw in cross-section, eccentric circles. The larger circle corresponding to the nanotube itself, and the smaller circle, to we did not know what. So we fantasized, and we said that it may be C₆₀ inside, and we actually had a few laughs about it. Two or three weeks later, we had a session on the microscope, and sure enough, we saw: circle, circle, circle."

Prof. Jack Fischer—Discovery of C₆₀ inside nanotubes—Unit 2.1

"The image is a projection of a three-dimensional object onto a single plane so the depth of field is zero, if you can get it to be zero, and it's kind of tough to make a mental image of what you are looking at, because you are projecting an image onto a single plane."

Prof. Roy Tasker—Modeling structures—Unit 2.1

"What computer modeling can do, is certainly save us a lot of time and trouble and expense in the laboratory by showing us which structures are theoretically impossible and, more important, which are possible. If we can show that a structure should exist, then we can go to the laboratory and make it."

Prof. Roy Tasker—Animating reaction dynamics—Unit 2.1

"The most powerful thing you can do when you're learning chemistry is to zoom down, in your mind's eye, to the molecular level and try to imagine what is going on and in a sense, try to understand the personalities of the reactants and products. If you can use more than one model to illustrate something, having each model showing a different aspect of the information conveyed, that's ideal. Because then students don't look at a particular model and say: that's reality."

Alain Nu—Observing magic—Unit 2.2

"Hello, my name is Alain Nu, Mystery Expert. You may ask yourself what a mystery expert is doing in *Reactions in Chemistry*—well, it just so happens that the word 'mystery' is in the word 'chemistry.' And so, to give you an idea of mysteries in chemistry, let me give you a couple of my own thoughts about mystery. You see, people are curious about mystery not because of its information but because of its lack of information. Unlike a puzzle that remains to be solved, the beauty of mystery is experiencing that which is unsolved, and perhaps the notion that things are not always as they appear. In the end the spectators are left with questions about things which have already happened, and events that have gone by. Now, it's true that in real life things are not always as they appear, just as they might not be in this very performance. Like for instance: Are those real spectacles that I'm wearing? Is there anything in this glass that I'm sipping from? Is there anything written on this piece of paper? Is this piece of paper actually on fire? What did I light this piece of paper with? And, is there a piece of paper at all? The answer to all of these questions is: It's all in how you see it."

Dr. Laurie Geller—Relating macro and micro—Unit 2.4

"Understanding the chemistry of atmospheric processes, for instance, the issue of ozone depletion, requires knowledge of a wide range of spatial scales. First, you need to do studies on the micro scale and look actually on the atomic level, and look at the reactions occurring between various types of chlorine compounds and ozone, and what's happening on the surface of little particles in the atmosphere. It's very small detailed chemistry which is in the heart of what's going on. But to place it in a larger context, you also need to be able to study atmospheric processes as a whole, as they occur around the globe. You have to understand the ozone and compounds that are made on one end of the Earth, and are transported to another end of the Earth. These are very central tools to environmental science, where you feed in little bits and pieces of knowledge that you learn from experiments in the lab, including the rate of a particular reaction between two molecules, and fit it into a framework of all important processes that occur in the atmosphere over a whole planet and hopefully, if the model is done well, you can recreate what you are actually seeing in the atmosphere."

Quotes, cont'd.

Jackie Olin—Autoradiography of “Jonah”—Unit 2.5

“Albert Pinkham, a writer, is famous for his use of images from the bible and Shakespeare. One of the paintings that he has done which was checked by autoradiography is the painting Jonah. It is a scene depicting Jonah being swallowed by a whale. It was interesting to us looking at it with autoradiography; we were looking at it very carefully for 10-15 minutes, and all of a sudden, one of the members of our group said: there’s a face in that autoradiograph.... It’s a portrait, one painting was painted over another painting. And the portrait painting was certainly not in the style of the writer.”

Jackie Olin—Analyzing the chemistry of paintings—Unit 2.5

“X-ray fluorescence can be used as a non-destructive technique for examining the elemental composition of a painting. So by knowing the energy of those X-rays, you can identify what that element is. When taking an X-ray source and a painting, and you focus the X-rays on the painting and the emitted X-rays can be identified, and so you can identify the atom and have some idea of what pigment it might be. If you find lead, for example, from X-ray fluorescence, you can’t be sure which lead-containing pigment it is. So you may go on to X-ray diffraction analysis. X-ray diffraction enables one to identify a compound, not only the elements in the compound, but the actual compound itself. It is very often a combination of techniques. Thousands and thousands of years ago, earth colors were used, in paintings in caves, for example. Those same earth colors are still in use today in many cases. But over time, there have been changes. For example, in the 19th century, during the Industrial Revolution, many pigments were manufactured. And today, a lot of pigments that are used by artists are manufactured...even discussing how materials change in time by oxidation, or by crosslinking, where small molecules combine with other molecules to form larger molecules. That process is important for a conservator for learning how things change with time. In order to do that, you need to have a background in chemistry.”

Alain Nu—New directions—Unit 2.5

“Chemistry is everywhere we go. Even in this spoon. With all the new advancements in chemistry, there is no telling where we will be, only a few years from now...here is for all of chemistry’s new directions...”

Dr. Lou Allamandola—Signals from within—Unit 2.7

“There are very distinct parts of the IR spectrum which tell you [about molecular structure]. It’s like a symphony or a rock band: if there’s no guitar, the band will sound very different than when there are three guitars and a bass.... These are all different frequencies.... In the IR it’s the exact same thing; we cannot see it but the instruments tell us: This is the frequency of the O-H, of the C-H, of the C-O. If you see them all together, you don’t know it’s a methanol molecule, but you know that they all are there.”

Alain Nu—Chemistry and mystery—Unit 2.7

“Predating the chemistry of our time and Abe Lincoln, early alchemists were in search of all life’s mysteries: the philosophers’ stone, the elixir of life, changing base metals into gold. Much of this work was cloaked in mystery. Hence, my being here. Does anyone here have a base metal that I can borrow? No takers, huh? I suppose we will just have to use this penny. Back in those days, the alchemists had far fewer elements to work with. However, from our airs to our winds, through the waters of our oceans, through the salts of our Earth, and through the fires of our suns, the Alchemists sought transformation, and from that chemistry was born.”

Students’ Ideas

Seeing the Atom—Unit 2.2

“An atom is so small that we cannot actually see it. We don’t have the equipment to see it. The people out there have it. If we had something like this in school (electron microscopes), it would be pretty nice.”

“They’re visible up to a point. If you look at a table, you’re looking at a bunch of atoms that were put together. So in reality, they are not really invisible, just that it takes millions and trillions of them to make a certain thing. Like, this computer is a bunch of atoms.”

Teachers' Forum

Visualizing the Micro—Unit 2.2

Tom Pratuch—"When we started this whole thing, someone commented about seeing the atom. We all know that you have never seen an atom; that has never occurred. And on a physical level we never can. So, to get them to understand that it is all representational, is [to explain] basically that we have got a good story which seems to work, but that we toss it out every time that it quits working. This is implicit, to get from the large scale to the small scale, to understand that it is a good story."

Dr. Michael Clarke—" [We need] to emphasize that these stories that we have are logical explanations of what has been observed and to warn them not to learn chemistry but to understand chemistry, because, if we observe something new that does not fit in with our preconceived notions, we need to change the story so that it is logically consistent with what we have observed."

Veatta Berry—"A lot of times it is the job of students to come up with analogies that address the invisible, like when they see a picture taken by an electron microscope, you may talk about how you might make a hand-print in clay, or—do you remember that device with all the pins? You could put your hand in and it could keep the shape of your hand. When you see the shape, are you really seeing the hand? Is your hand really there? This helps the students develop what we had already developed for ourselves."

Gannon Sugimura—"One big misconception that kids have is that the air is actually not there; that there is nothing around us. If you have one of those scales, you could put two balloons on it and they balance out...then you fill one with air. The kids are convinced that the balloons will still balance out. That's a really concrete way of showing them that the air is really there."

Sharon Walton—"Sometimes challenge them to figure out a way to show something that you've identified as a misconception and get them to discuss it."

Tom Pratuch—"On the first day of class, what I focus on is letting them do something."

Veatta Berry—"Really it's thinking about...as a teacher, how you understand chemistry yourself. What do you really picture in your head, and thinking how you are going to get the students to see the same picture. I tell my kids that I see particles moving around in my head; I have this picture, I see it. I know you don't, so I'm going to help you see it."

How To Teach for Thinking—Unit 2.2

Tom Pratuch—"The bottom line is that we're there not to make them chemists, but to teach them a way of thinking."

Irene Walsh—"Along the line that you try to teach them a way of thinking, and how you figure out what something is when you can't even see it. You get shoe boxes and put some different kinds of objects in them, like bolts and ping-pong balls or a brick, and pass those boxes out and have them not being able to open, but shake them around and let them observe. From their observations, try to figure out what kind of thing is in there. Explain how people, because of the background they had, came to an understanding of what the atom is like."

Caryn Galatis—"I traditionally started out the first year of my chemistry course with the old candle study: write out as many observations as you can. It's usually a homework assignment the first day. We go through what an observation is, talking about it being quantitative and qualitative. Then we start talking about what's burning. They list the regular things: the candle is burning, the air is burning. Then we successfully go through a logical reasoning to prove that nothing is burning. Then, we go back and collect some more physical evidence like passing a note card in the flame and finding it's hollow. We come up with a list of observations, which is a couple of pages long, and they're just amazed, because they don't sit and think about the world around them. They subsist in it but they don't think about why things are the way they are, what things are made up of. At the end of this conversation, they start to talk about all these things about the candle that they hadn't ever thought about. I tell them that there is a whole book written about the burning of the candle...and they just can't believe it."

Math in Chemistry—Unit 2.3

Dr. Leslie Pierce—"I was thinking, as we were having this discussion about getting students to understand things that they can't see, that historically, teaching students chemistry in high schools and universities involved having them do lots of calculations about things that they cannot see. You have a couple of problems there [in teaching chemistry]. One, is the things [the students] can't see, and two, it's the first time that they really have to deal with a quantitative science. And when you combine the two—trying to do math involving things they can't see, this adds an extra dimension of difficulty in trying to come up with models which can help them correctly visualize what's going on."

Gaining Experience—Unit 2.6

Caryn Galatis—"I think one of the advantages that we have as chemistry teachers is that our subject nature lends to always being able to show them something interesting, or something that does not make sense—discrepant events—and we try to ask them—why? And getting from there down to molecules interacting with each other and the forces between them. We could always pull something out of the hat, I mean, a lot of what we are doing in demonstrations in chemistry is like magic for the kids, and kids are fascinated by magic, anyway. And it's getting that to draw their interest, and to go on from there and talk about the level of what is really going on and get down to the chemistry of it. We can always show them something fun and interesting."

Al DeGennaro—"So much of the stuff you do on the tabletop is somewhat inconclusive: you show them something green changing into something yellow and you tell them this is a compound and this is an element. How do they know that it is not the other way around? And so I think that the idea of smallest and smallest piece is not something that you could show them on the tabletop, and that's kind of the point."

Unit 2.7—Relating Macro and Micro

Irene Walsh—"In introducing chemistry and the idea of chemistry, I start by saying that chemistry is the study of matter, and then I do a series of three demonstrations, showing a precipitation reaction, formation of gas and a color change. Then I say that in all these instances, a chemical change has occurred. And later on we talk about evidences for chemical change, so this is right in there."

Caryn Galatis—"Our biggest problem is that 90% of what they see isn't really on the level of what they're expected to know. You see the color change, you see this happen, but they have to understand it on the level of atoms and molecules, whether it's symbolic, whether it's demonstration or calculations; it is something that they are never going to see. So we have got to, about almost everything we do, cut out models or do something where they can physically manipulate on the table."

Dr. Michael Clarke—"I am kind of lucky. I'm in Washington, D.C., and last year was the day of the family march, and on the news of cameras from up above. So I explained to them, that when you see a crowd from up above, how it looks and how it behaves was totally different from when you're down on the ground seeing individual people. So that kind of separated the micro, which is looking at an individual person, vs. looking at the macro, which is looking from a helicopter."

Workshop 3. Energetics and Dynamics

Scientists and Experts

Dr. Jean Posbic—Trapping solar energy—Unit 3.1

"It's really a combination of really chemistry and physics: the solar cells are made out of silicon; it's a semiconductor, which is very abundant on Earth. The photovoltaic process itself is fairly simple after all. Photons from the Sun hit the silicon. If they have enough energy, they are going to split one of the silicon atoms into a silicon ion, Si^+ and an electron. If you don't do anything with them, they recombine, because everything is at stable conditions and is neutral, so the charge will be just the same. If you attach wires on the front and the back, after creating physical field, a positive/negative field, you will be able to separate this electron and the silicon positive ion for enough time to have them go out of the cell, go into another appliance do some useful work there, and go back through the back of the cell."

Quotes, cont'd.

“So, it’s fairly very simple, because we’re just splitting an atom into an ion and an electron and the electron goes out into the load [electrical appliance], comes back through the back [of the solar panel] and then the circuit is closed and we have enough energy for the device.”

Dr. Jean Posbic—Manufacturing solar power—Unit 3.1

“Phosphorous is a group V element, it has an extra electron in its last layer, which means that it is going to share it with the silicon around it. Which means that it is an n , negatively doped area of the silicon. Hence, you have a field, a negative to positive field, that when the photon hits the solar cell, will create a field to separate the electron from the silicon ion, during this process.”

“So here in this case, this machine is going to do the printing on the cells. We are printing on the front and on the back of some metals in order to capture the electricity from the solar cell. The back is completely covered with silver, because we don’t have any light coming from the back, and we have a very conductive material, silicon is very good at that. The front is covered with very thin fingers, that allow light to come through the wafer, and create electricity from the Sun. The cells that we saw before, the gray cells, reflect up to 20% of the light that hits them, because of the nature of the color that they are made of. In order to minimize the reflection and maximize the electrical efficiency, we add on the front of the cell a very thin layer of titanium dioxide. We trap more of the light using this titanium dioxide layer. So some of the light is trapped, goes in, is reflected, comes back in, and gets more chance of doing some work in the solar cell. Only the very strong and the very powerful light, which is the UV, and the blue, is reflected, and we see them. That is why the cells are blue.”

Dr. Jean Posbic—Using solar energy—Unit 3.1

“The solar module will live for about 30-40-50 years. This means that it will be generating for the next 30, 40, 50 years just free energy. Obviously, that’s a great advantage for our Earth; we have mined a lot of the fossil energy. This is finally a way of renewing some of the energy, and being green for the Earth.”

Phil Grucci—The chemistry of fireworks—Unit 3.2

“Fireworks, on a chemical level, are a combination of oxidizers and fuels. The oxidizers form a free form of oxygen when energized or when heated, and the fuel creating the burn rate of reaction in a pyrotechnic chemical reaction. Examples of oxidizers that we may use are potassium nitrate, which is used as black powder; potassium perchlorate is another oxidizer which is used, because it is very energetic and it is utilized in the noise-making devices that you see. Some examples of fuels are like sulfur that we use in black powder. We use also some metals: some metals give us the twinkles, they serve also as fuels with different types and sizes; they can also be utilized as fuels. We can look at a fuel, such as aluminum or titanium, and you look at the particular size; our ability to get to this particular micron size gives us the ability to control the burn of this material. Chemistry is extremely important for us, to be able to continually refine that, and gives us the ability to create new and exciting effects.”

Prof. Roy Tasker—Animating NaCl crystals—Unit 3.3

“Take, for example, a very simple reaction: adding water to salt which is dissolving. What you see is macro level: first you see crystals, then you stir it up. After a while the crystals disappear and you only see a clear liquid. What I’m asking you now is to imagine that you go down to the surface of one of these crystals. What would you see, what would you imagine, as the water molecules come down, let’s just talk about what is happening in this dissolving process. What is up here, for example, is a crystal of sodium chloride; the green spheres represent the chloride ions, whereas the bright spheres represent the sodium ions. As I start the animation, they start vibrating and moving. Now the water molecules are surrounding the chloride ions as piranhas eating a piece of meat and pull the chloride ion out, and then they surround S ions and pull them out. You notice that there is a bit of competition.”

“I think that the point I’m trying to make is that in an animation like this you can get a number of key features across, one of them being that, now the ions of the sodium chloride are vibrating, moving. Now that’s something that a lot of students don’t really appreciate because they think that if something is a solid that everything inside must be still, but they are actually always moving. The ions are of course always jiggling around, and melting is when you add heat, the ions move and vibrate until suddenly the whole structure just breaks down, and that is actually what melting is.”

Quotes, cont'd.

Prof. Darleane Hoffman—Teaching about radiation—Unit 3.6

"I think it is the same as Madam Curie said: that nothing is to be feared, only understood. What I try to make the students aware of on the first day of a nuclear chemistry lecture course is that there's a whole continuum of radiation, and it's a natural thing. We go all the way from radio waves which are long and not so energetic, through micro waves through infra-red, through UV through X-rays, through gamma rays, through cosmic rays. This is a natural thing that's been going on for billions of years. Since the synthesis of the elements in our solar system, uranium and other naturally radioactive isotopes have been decaying, so there's less radioactivity now than there used to be."

Prof. Darleane Hoffman—Measuring radioactivity—Unit 3.6

"This is the kind of little solid state detector we use for alpha and fission counting. They are surface barrier detectors, and they have a thin gold coating on the top. On this kind of detector, we turn the sample and count and then we evacuate the chamber and we record it through these various amplifiers, and we can count both alpha particles, which, as I said, are the nucleus of the helium atom and most of the heavy elements decay by alpha emission, and sometimes spontaneous fission, which is similar to the neutron-induced fission in reactors, and so forth."

Students' Ideas

About Nuclear Power—Unit 3.7

"When I think of it, I think of a nuclear bomb."

"I know that nuclear is like real power."

"Alpha, Beta, Gamma, and emissions."

"Like nuclear power, like nuclear weapons, something like that."

"A chemical mass or structure or something."

"Usually bombs."

"Family, the nuclear family."

Teachers' Forum

Chemistry or Physics?—Unit 3.7

Dr. Michael Clarke—"I also teach physics, and what I tell the students is that atoms do not know that we humans have decided this is chemistry, this is physics, and this is biology. Atoms do whatever they do, and we study them and once we look at the same phenomena it doesn't matter what we call our course, the phenomena is the same. The explanation is either logical or it isn't. So why call the explanation physics, chemistry or biology? Because the explanation must be the same if it is a logical explanation of everything that we've observed. So I tell them: Be careful with these labels: physics, chemistry and biology, they really don't mean as much as we would like to pretend that they do."

Caryn Galatis—"I think that it's important that the kids see the connection between the sciences. I think we do it a service in this country by teaching them, supposedly, in isolation from each other and sub-divide them into all these little niches. I think it is really important that when we look at these things called physics, biology, and chemistry, many times we are looking at the same thing from different perspectives; it's all interrelated. It's all about understanding our universe and trying to make sense out of it. It's just that chemists look at it in one way and physicists look at it another way. And in terms of energetics and dynamics, chemistry and physics are so tied together, that you cannot separate them."

Workshop 4. Theory and Practice in Chemical Systems

Scientists and Experts

Dr. Elsa Reichmanis—Ultra miniature parts—Unit 4.1

"We've been able to demonstrate a working flash memory cell, having 60nm features. It was done a little over a year ago, and at the time it was the world's smallest working device that had been fabricated using optical lithography, which is the technology that's used in most device fabrication facilities today. We are able to get features as small as 60nm, which, when you think about it, is about one third the width of the wavelength of light. When I started at Bell Laboratories, a little over 20 years ago, the conventional wisdom was that you could never produce something smaller than the wavelength of light, simply because of physical principles, diffraction facts which would prevent you from doing that."

Sylvia Ware—Chemistry in everyday life—Unit 4.2

"Everything we wear is touched by the hands of the chemist. The music we hear is touched by the hand of the chemist. The perfume in the air in Washington cocktail parties is all chemicals. Chemistry is not going to go away. What we do have to do is to make sure that both chemists and non-chemists know a responsible way of working with chemistry and everything that it can do for us."

Dr. Hugh Salzberg—Chemical equilibrium—Unit 4.5

"Because it was on a large scale, the reaction was the reverse of the reaction. Then he, Berthollet, began to wonder: 'If that is the reverse of the reaction, maybe other reactions are reversed?' And he went on to 10-15 years of study and found out that many reactions were reversed."

Dr. Lou Allamandola—Systems in equilibrium—Unit 4.6

"If you take that vinegar and oil dressing, the oil is on the top and the vinegar is on the bottom. If you shake it up, it is out of equilibrium. In cells it's the same thing. All day we're eating food and drinking water...the system is always changing. Something is coming in from the outside and it's excreting something [else].... It's never always doing the same thing, just sitting there."

Prof. Roy Tasker—Water dissociation—Unit 4.7

"Let me show you an example of an acid-base reaction, which occurs just in liquid water...we start off with two water molecules which just hit one another. They aren't bonded together but they have a fight, and a hydrogen atom is involved in a tug of war between the two oxygens. What is actually moved from one molecule to the other is the hydrogen atom, not the electrons. It's like a flea jumping from one dog to the other. You don't see the flea, but you can see the itching...."

Students' Ideas

Chemical Systems—Unit 4.2

"I'm not sure what a chemical system is."

"Chemical system...I don't think I've ever heard of a chemical system...I really know nothing about chemistry."

"I guess if it's a system and it's a chemical system, it's got chemistry in it and, depending on what that system is, there are various aspects and usually there's a cyclic flow to it, like in the carbon cycle."

"A chemical system...well, I really don't know, but it could be the combining of one chemical with another, to make something, combining these two things might be a chemical system, to make something reactive or something new."

"And if you ever want to make something, you have to know about chemistry in order to put things together, to create something totally new, you can create, I'll make up a word for it, you know, to create electro-magno-pluto ...that's something weird, you could give it any name you want."

Teachers' Forum

Based on the Familiar—Unit 4.2

Kelly Rottmann—"I think you have to relate it to what they are used to. Students are used to, for example, chemical reactions. If you can relate it to dating, which is something that they're all very familiar with, different types of reactions, different couples in a relationship. And when we do that, the students are very interested in that because that's something that they are very interested in. So I think it's coming back to their everyday lives."

Models for Equilibrium—Unit 4.6

Irene Walsh—"What I'm always trying to do is take concrete things and use them to make analogies so that students can get some concrete idea of something first and go on from there. There are many of those that I use in introducing topics. For example, I use an analogy with aquariums, filling aquariums, when I'm trying to teach equilibrium."

What Are Real Chemicals?—Unit 4.7

Caryn Galatis—"We have to break this notion that you are not really doing chemistry unless you are using 'real' chemicals. I mean, what is a real chemical and what is not?"

Dr. Michael Clarke—"We have to start letting everybody know that everything is a real chemical. Vinegar is a real chemical, lime juice is a real chemical."

Sharon Walton—"And that anything can be dangerous if it is used in an incorrect way."

Caryn Galatis—"The kids have this misconception, too. If it is around the house then it is not chemicals."

Tom Prutch—"That's one that I love to address by giving them pH strips to take home. Let them find out that the chemicals that they have at home have a higher concentration than anything that we are allowed to give them in the lab by the safety rules. I think that the idea that everything else is not chemicals, causes them to have this divorced world of chemical systems, which is not part of real everyday life."

Dr. Leslie Pierce—"Here is a challenge that we have, though: If we are going to talk about household chemicals as a basis for their understanding of chemistry, we should also have to teach students how to apply some of the techniques and tools that chemists use in the lab to working with these materials. What we are trying to do is to use these everyday substances, and give the kids the opportunity to use the tools that traditionally chemists use."

Caryn Galatis—"It can be a simple lab as the one that we do in the observation on pH, once we learn what acids and bases can do. They can try out a lot of acid-base indicators; they can then extend it to thin layer chromatography, which is a very common technique, and spectroscopy. Vegetables and fruits and their colorful components can be used for a lot of different things."

Tom Prutch—"To get them to accept whatever your data is, and the conclusion that you then reach, based on the analysis of whatever you actually measured, and then explain the discrepancy if in fact it is obviously discrepant from what it should be. Focusing on such thought skills and affecting their way of thinking is more than just chemistry."

Workshop 5. Chemical Design

Scientists and Experts

Prof. Richard Wool—Self-healing materials—Unit 5.1

"I have seen experiments done by the group at Virginia Tech, where they are taking sheets of this ionomer and shooting bullets through it and a bullet makes a hole, but the hole instantly heals. That's a very interesting case, because what the bullet does, it tends to fluidize the polymer sheet locally where the bullet hole was, but at the same time you have a large number of metal ions which tend to cluster together again...and it instantaneously heals."

Quotes, cont'd.

Dr. Kevin Chapman—Designing chemicals—Unit 5.2

"We, as organic chemists, are molecular engineers. Our tools, instead of wood and steel and hammers and nails, are atoms and molecules. And we have learned how to put these together to build molecules...so when we design, it's no different than when an architect designs. You ask yourself which atoms you want placed where, what the ultimate architecture of the molecule is, and then you design a route to build it. Then you...actually make the molecule."

Dr. Jesse Meyers—Corn syrup in Coca-Cola—Unit 5.4

"At MRC there was a chemist, by name of Martha Jones, who was not working for Coke, and who was instrumental in developing a lot of these new products that MRC was so innovative about. She has been called by many in the industry, the Mother of HFCS. And she made sure that this product was up to the specific levels of each of these franchise firms and that [corn syrup] could be used interchangeably with sucrose."

Dr. Michael Robbins—Up-scaling processes—Unit 5.5

"We are working with very small quantities of compounds so we can put it into biological assay, and find the molecule that we eventually want to use as our drug. Once we have identified this molecule, we need to think about how to produce it in large quantities, on a kilogram scale. Typically, here we produce between 1-20 milligrams of our compound. We then want to go to the factory scale and produce it on a 20-ton scale or kilo scale, which requires us to really focus on our synthesis and make our synthesis as elegant as possible. You want the fewest number of steps, you want it to be economically feasible, and you want it to be environmentally friendly. And that really causes one to focus on the chemistry in order to scale it to the kilos."

Nellia Jenkins—Drug chromatography—Unit 5.6

"We are using chromatography not only for inks. In the same way inks separate, drugs separate as well. If you have heroin, cocaine, and codeine—those are all alcohol-type drugs. You can run them and they will separate. We use larger TLC plates for drugs because we want them to run a longer distance. In drugs it's a single compound, and you will need a longer plate so it will separate in the correct shape. Now you can identify drugs with mass spectra, but we need to have a known to run with it, and the known we identify on a TLC plate. Just because a new technology comes out, doesn't mean that this doesn't work any more. We use it because it works."

Dr. Kevin Chapman—The beauty of being a chemist—Unit 5.6

"The neatest thing about being a chemist is making things that have never been made before, and we do this all the time."

Prof. Richard Wool—Combinatorial chemistry—Unit 5.6

"The beauty of chemistry has always been that there is an infinite number of ways that you can connect molecules. And we have not yet gotten close to getting all of the combinations. This is where the field of combinatorial chemistry comes about. That explores the many different ways to connect the different atoms to give you materials with different properties. It's back to basic chemistry. Sticking together balls and sticks. If you can do that in your hand with balls and sticks, you can do that on the molecular level, because the rules of engagement are well known. How you put them together is only controlled by your own imagination."

Students' Ideas

What Is Stoichiometry?—Unit 5.2

"I'm guessing something to do with how stuff works, I don't know."

"Mathematical terms? I don't know."

"Sounds like something you eat for dinner."

Teachers' Forum

The Tools of Chemistry—Unit 5.2

Caryn Galatis—"It is all new to them. It is novel for them to think that cooking has anything to do with chemistry."

Dr. Leslie Pierce—"Here's a challenge that we have then: If we are going to talk about household chemicals as a basis for their understanding of chemistry, we also have to teach students how to apply some of the techniques and tools that chemists use in the lab to working with these materials. So that is how we begin to quantify and measure and compare things, and this really is a challenge because we don't find too much help in the books and lab manuals that we get. What we are trying to do is to use everyday substances with mathematics and modern techniques that traditionally chemists use."

Workshop 6. The Chemistry of Life

Scientists and Experts

Dr. Lou Allamandola—The building blocks of life—Unit 6.1

"In a conversation I had with a friend working at Chevron Research in New Jersey, I showed him some of the spectra [from the Orion Nebula] and he said: Boy, that's funny, you ought to look in this old paper by Rosen and Nobocopf on soot-studies. So, I found the paper, and sure enough, the spectrum of auto-exhaust soot of Los Angeles matched the best spectrum from the Orion Nebula. That's what started us realizing that soot is made out of carbon, high temperature carbon and aromatic molecules, which are similar to those in interstellar nebulae. From there came this wonderful theory, that the conditions of outer space are just right for turning simple elements into molecules which are the building blocks of life."

Dr. Lou Allamandola—Simulating interstellar clouds—Unit 6.1

"We can't build a black hole or a supernova in the lab. But we can do a very nice job making a little cell, the size of a shoebox, in which we can get very low temperatures and very high vacuum, and expose it to radiation similar to the radiation in the spectrum of starlight, and we can follow the chemistry within this shoebox."

Dr. Lou Allamandola—Building the molecules of life—Unit 6.1

"If you're going to build life, odds are it's going to be made from carbon, nitrogen, and oxygen. We found in our lab that we can make very complicated things, relative to our starting materials; we are just beginning to understand this kind of chemistry."

Dr. Lou Allamandola—Putting life into molecules—Unit 6.1

"When we add water to this material and look at it under the microscope, it starts to self-organize. What this means is that little droplets of it will form membranes, which are little hollow spheres that can separate the chemistry of the inside from the outside. In addition, if you turn off the lights and expose it to UV light, they glow. They harness energy from the outside environment, do something with it, and get rid of the excess energy."

Dr. J. Craig Venter—Cells are dynamic—Unit 6.3

"Cells are dynamic living entities, but the textbooks let us think that they're static. The protein complement of a cell changes from one minute to the next, responding to environmental influences, responding to communication from other cells, responding to what we have eaten, and to what we are experiencing. Even when we are sitting still, we have billions of changes going on constantly."

Quotes, cont'd.

Prof. Terry Collins—Natural and synthetic processes—Unit 6.3

"When chemists are designing reactions, they are usually after what is called selectivity. Selectivity is when two chemicals come together, A+B, to give you the one chemical that you want, C. A truly selective reaction does just that: $A+B \rightarrow C$. In order for nature to run something so complicated as our cells, it must run millions of reactions with exquisite selectivity. But nature gets its selectivity in a very different manner than chemists and chemists are very good at getting selectivity. Nature has reduced the tree to a very limited arsenal of elements, and the enzymes are fantastic machines with very elaborate designs. Chemists use the whole Periodic Table, and that is the main reason we pollute. One of the major ways to reduce pollution is to move the elemental balance of chemical technology, closer to the elemental balance of life, wherever possible."

Prof. Linus Pauling—The discovery of protein folding—Unit 6.5

"I built so many models by 1948, that I could start to do it in my head, or just on a sheet of paper. What's wrong about this plane, in the structure I put here [protein structure] is that the angle between these two bonds is 180° . But it ought to be 109.47° , the Tetrahedral Angle...I don't think I got any smarter by 1948 than I was in 1937, I didn't know anything new, but I said suppose that all of these residues are equivalent to one another. I knew then, that the structure that they would have had to assume would have been that of a helix."

Todd Ruby—The chemistry of wine—Unit 6.6

"Sweetness is a flavor that we perceive, and even though there's no real sugar left in the wine, there is the element of sweetness that... is given by the chain of molecules, which are basically carbohydrates left from the fruit. Also, the "Baberra" wine has a naturally high acidity but it has what the white wine and the cherry didn't have: tan. There is another kind of acid, tannic acid, or tartaric acid, I should say, which is the reason red wine goes so well with meat: the tanning actually attracts proteins. And when you are having meat, you are having proteins. People say, "let me include in my bowl a piece of bread." When we are tasting a lot of wine, what is actually better is a piece of Melrose beef, because the protein in the meat electrically bonds with the molecules of the tan, which come from the skin of the grape. All red grapes make white wine, which becomes red when the juice is left with the skin, which has the pigment and the tan."

Prof. Terry Collins—Chemicals in medicine—Unit 6.7

"The students ought to understand that if they cut themselves, and put [$<3\%$] hydrogen peroxide on their hands, they are going to see bubbles. If they leave it there for too long, it is going to start hurting, and eventually, if they rinse it off, they will see white stuff. The bubbles are oxygen coming from the hydrogen peroxide. This occurs because metal ions in the body fluid, mainly iron, catalytically decompose the hydrogen peroxide in a process that is called Fenton chemistry. It produces the hydroxyl radical which is a vicious reagent. It will attack virtually all organic compounds and cause them to decompose. If you cut yourself, it's a very good reagent because it sterilizes the place due to its very reactive nature."

Prof. Richard Wool—The chemistry of the human body—Unit 6.7

"Our own bodies are extraordinary biological chemical manufacturing systems, where we use our genes to make highly complex molecules. Bioscience has made tremendous advances in the last 10 years, and so in the future you will see a lot of the chemistry facilitated by bioprocesses. We have fermentation processes, genetic engineering of growing things in a field, a combination of the two, combinations of traditional chemistry, boiling things and adding, introducing things into plants and microbes in bacteria. We are headed towards the ability to design highly complex molecules such as we are. We are a mass of highly sophisticated molecular structures, billions of years old. And we are trying to understand ourselves for the first time. And it didn't take an extraordinary amount of energy to create these molecules; we are all very low-energy synthesized beings."

Students' Ideas

Chemistry Is in Everything—Unit 6.2

"We see all sorts of things happening in life, like right now, when we're breathing, that's chemistry there. Also, everything we touch, everything we see, all those particles that we ought to know what they are...everything here is chemistry, just looking."

Quotes, cont'd.

How Are We Affected by Chemistry?—Unit 6.7

"We are affected by chemistry because basically we are made up of chemicals.

"If I know what the chemical make-up is, I know what will happen in chemistry.

"The brain is a big chemical reaction"

Teachers' Forum

Relating Biology and Chemistry—Unit 6.2

Dr. Leslie Pierce—"Because most of the students in class came recently from a biology class, we also try to begin chemistry by relating to the things that they already know."

Caryn Galatis—"If you can take what you are doing in a first year chemistry course and relate it back to what they did in biology—they talked about the chemistry of life, chemicals in the cell, the basic biochemical reactions on the cellular level. If the chemistry teachers make themselves familiar with what the kids did in the course before theirs, they can find all sorts of things to talk about. What you introduce in chemistry relates a lot to chemistry of life."

Dr. Michael Clarke—"I'm at a school of the performing arts, where everybody is concerned about appearance. The food that you put in is all chemicals. Everything has its caloric value. So keeping a journal of what you put in and how much energy you are expending everyday, and then weighing yourself everyday, relates the chemistry of what you eat and the energetics of what you do to your weight and to your appearance, which for most of the kids where I teach, is the most important thing in their life."

Caryn Galatis—"I think when you get into equilibrium, you can always relate to things from biology and physiological systems. Maintaining a pH balance in your blood, and why that's important, or why you run and get cramps."

Irene Walsh—"Sometimes after we are done with equilibrium, and looking at LeChatalie's principle and how the addition of one thing shifts the equilibrium, and you can shift it back and forth, I try to bring in the fact that there is an equilibrium within the body. This exists between different sorts of reactions, and if you start taking drugs you can shift these reactions in ways that could injure you permanently. We really are all chemists, without even thinking about it, we run millions of reactions and they must be maintained at equilibrium."

Tom Pratuch—"We started talking about what happens if a child goes under the sink and gets into chemicals. From that point of departure I found a whole category of students who are not usually interested in chemistry suddenly sitting up, and I talked to them afterwards about being responsible for their brothers and sisters at home. They knew of somebody whose child had been poisoned. And when it suddenly sunk in, why you cannot dilute chemicals in a child's belly...those students are pulling A's in acids and bases because it was taken to a whole level for them. It's what they came in with that takes the direction for me, not what I come with."

Workshop 7. Chemistry and the Environment

Scientists and Experts

Dr. Laurie Geller—Introducing ozone—Unit 7.1

"Ozone is actually a very simple molecule. It is made up of three oxygen atoms, and it has a chemical formula of O_3 , but it plays a very complicated role in the Earth's atmosphere. It can either be harmful or beneficial to humans, depending on where in the atmosphere it resides."

Dr. Laurie Geller—CFCs in the atmosphere—Unit 7.1

"When they created CFCs, they purposely made them very strong, because that made them very useful for industrial processes. But that also made them different in that they basically survive in the lower atmosphere for a quite a long time, and unlike most molecules, which get washed out, they hang out there for a long time and eventually make their way up to the stratosphere. When CFC molecules get to the upper atmosphere, they get exposed

Quotes, cont'd.

to strong UV radiation, that has enough energy to break the chemical bonds of the molecule, and finally the CFC molecules meet their destruction in the atmosphere. The problem is that what you are left with is a free chlorine atom, which is very reactive. The basic reaction is between chlorine and ozone, and in the next step a lone chlorine atom is regenerated; such that one chlorine atom may destroy up to 100,000 ozone molecules."

Dr. Laurie Geller and Dr. Carlos Gonzalez—The hole in the ozone layer—Unit 7.1

"There have been many efforts to design alternatives [to the repair of the ozone hole]. We have a whole group working on looking for compounds which decompose before they reach the ozone layer."

"There have been lots of ideas about how to fix the chemistry of what is going on in the atmosphere. The only way that we know that will work and is safe, is to stop releasing these CFCs into the atmosphere."

Prof. Hugh Salzberg—Mercury in gold mining—Unit 7.4

"There was a method by which the mercury was shaken up with material containing gold ore, dissolved, and squeezed through a piece of leather. This is probably the origin of the story about Jason and the Golden flits. The gold mines in Asia Minor used that, and the flits were golden flits."

Prof. Hugh Salzberg—Mercury and environmental consciousness—Unit 7.4

"People died, not that they cared very much; life was cheap in the Roman Empire. But the Emperor Hadrian had some humanitarian impulses along those lines. They tried to limit the hours of exposure of miners to mercury, prescribing showers, washing clothes, and so on."

Prof. Terry Collins—Water disinfection—Unit 7.5

"What we've heard from the Indians of the continent, Latin America, and parts of Asia, is that the most important technology they need is safe drinking water. In Bangladesh, the monsoon rains came and stayed two months longer than usual, and literally flooded much of the country. The irony of this is that people can't drink this water. They can't drink it because of pathogens in the drinking water. We had the problem in the U.S., and we used a variety of technologies, the most significant being using chlorine. The chlorine kills the pathogens, and we can drink the water safely. But you can't really take chlorine and the technology you need to work with it into a small village in Bangladesh, because of the reactive nature of the chemical. But you could take a bottle of hydrogen peroxide, and Calais pills, which would attach themselves to the pathogens. The hydrogen peroxide and the Calais would then kill the pathogens, and you could drink the water safely. It could be done very inexpensively. We haven't solved this problem, but that's our drinking problem. We started with water disinfection 20 years ago, and we still want to do it."

Prof. Richard Wool—New composite materials—Unit 7.6

"These are actually the very first composite materials that we made with soybeans. This is part of a round-tape bailer that was made up for John Deere. To mass-produce these, we worked with several fabricators on the outside, and these are currently being used. John Deere currently switches from metal based blades to composite material blades, and the possibility of using the farmers' own soybeans to make combined harvesters from their own products is very appealing."

"There are several reasons why people are attracted to these materials. From a fundamental property point of view, they are pretty much the same as petroleum based materials. They do have some exceptional impact resistance. But I think most importantly, these materials are very environmentally friendly; they are made from renewable resources. When you look to the future, and you run out of oil in 70 years, and of natural gas in 80 years, you would like to maintain your life-style, affordably, with low-cost, sustainable materials this is a real vision of the future."

Prof. Terry Collins—Are we a sustainable civilization?—Unit 7.6

"At the introduction to my lectures, I always ask my audience: Do you think that we live in a sustainable civilization? I have asked almost three thousand people this question, including the scientific-intelligence leadership of the world, and nobody has raised their hands and said that we live in a sustainable civilization. As you peel the

Quotes, cont'd.

time back they say that we might only be sustainable for decades. This is clearly something very, very central to our future, and the really exciting thing about it is that chemistry is really big in this. Chemistry can do wonderful things, as it has already done, for humanity. We reflect so much on the negative things, but it has done so many wonderful things, that it's also central to our continued healthy future."

Teachers' Forum

About Water—Unit 7.2

Lisa Morine—"I do the water cycle in September. I tie it into solutions and how water is a universal solvent, and has things dissolve in it. There's a lot of chemistry in just water."

Measuring Water Samples—Unit 7.3

Caryn Galatis—"We have a catchment lake which was built fairly close to school, we walk the kids there and take some water samples also. We do lots of stuff about chemical analysis using this lake. We are teaching filtration techniques using the dirty water samples; it could be calculating percent organic vs. percent inorganic in samples, and salt sediments."

Aluminum or Platinum?—Unit 7.6

Tom Prutch—"When the Washington Monument was originally built, the debate was whether to get an aluminum cap or a platinum cap. And since all students know that and recognize that, we go cross-curriculum into American history of that time. That gets them back to why were aluminum (which for them is a wrapping that you drop) and platinum (which is considered something wonderful) considered on par with each other. And we get back to what it was like at that time, what was the state of chemistry and the available knowledge around the world at that time, and what you could think is absolutely true: aluminum is rare, difficult, impossible to use, but suddenly becomes totally different. We talk about the economic effect because I believe the cap was taken off during WW2 with aluminum scrapes on it, and the effect that it would have if we had a platinum cap on there now. They made this simple decision because it was going to cost them the same, either way."

Environmental Chemistry—Unit 7.6

Caryn Galatis—"Kids naturally gravitate to this topic, so we usually pick a few labs during the course of first year chemistry and have them either go out to get and analyze samples, or have discussions on these topics and come up with their interest in acid rain. When they get into acid-base chemistry, we talk about the misconceptions that they have. They have no idea where it comes from or what the causes are. How environmental protection aspects either influence or do not influence air quality. They are totally unaware, and they have no idea that the air is much cleaner than it was 10-20 years ago. And impacts like that. So these topics are really easy to get into, almost any unit that you do in chemistry. The kids actually come up with these questions, and if they don't, you make sure that they have them."

Workshop 8. Chemistry at the Interface

Scientists and Experts

Dr. J. Craig Venter—Deciphering the human genome—Unit 8.1

"In 1987, when we got the first automated DNA sequencer, that actually read DNA out into a computer based on four fluorescent dyes which were attached to the four chemical bases which form the DNA alphabet—that's when I decided that at some stage, I was going to set up a factory and try to sequence the entire genome. This was a very multi-disciplinary effort in areas in which I was not an expert: I have never built a super-computer before, the mathematics were far beyond any training that I have had, we had to develop all new lab procedures."

"We had everything from physicists to computer engineers, to software engineers, to molecular biologists, biologists, chemists; it's a pretty broad spectrum... and only because it was a whole team that worked together, did it work."

Quotes, cont'd.

Prof. Laura Niklason—Tissue engineering—Unit 8.1

"Our lab is essentially trying to grow arteries in the laboratory, from a patient's own cells, which might be useful for bypass surgery. To grow these vessels, what we are using is a bio-compatible, biodegradable polymer, made from a synthetic polyester called poly-glycolic acid. In this incubator, we have a system, which mimics the human body in many ways. Our goal is to take cells from a patient, and grow them on biocompatible polymer scaffolding in the lab, in the presence of certain biochemicals and supporting protein and elements, to help the cells grow and make proteins in the extracellular matrix.... We are working on adding in a gene called telomerase into our vascular cells, to try to make them essentially live longer in the laboratory and to make them feel, instead of being old cells from an old person, trick them into believing that they are young cells from a young person. We found that young cells grow better in the laboratory, make more protein and form vessels better than old cells."

Sylvia Ware—Chemistry is central to life—Unit 8.2

"If I were in charge around here, I would basically say that chemistry should be a compulsory subject for every student in the U.S., whenever they can take it, whether it be ninth grade, tenth, eleventh, or twelfth grade. It's not because I'm saying we need lots more chemists, or everybody should be a chemist, it's because chemistry is a basic subject, and so many of the things that happen around us in life happen because of chemistry. Good things and bad things. And there are many societal issues facing us today that do involve an understanding of chemistry, in order to be solved. And they will be solved, not just by chemists working with solutions, but also by a whole array of people working on solutions."

Dr. Lou Allamandola—Chemistry is everywhere—Unit 8.2

"I think it is very underestimated today how dependent we are and how friendly chemistry is: from the clothes we wear to the food we eat, to the furniture we sit on, to the cars we drive, chemistry is a central science, it is critical to all of these things. We just take it for granted. And at the same time, it is very unfortunate that the word chemical, in these modern times, has a negative connotation. I can guarantee you that we would all be dying from Bubonic Plague and all sorts of other things which are terminal, if we threw all the chemistry that we know out, and go back to the old style. It's a wonderful science, it's got great applications, and it isn't as hard as people say it is."

Rebecca Huff—Forensic chemistry—Unit 8.3

"Everything's different. No case is ever the same. I worked as an analytical chemist and everything is routine, it's the same, but in case work, there's a lot more challenge, and trying to figure out something, and it is satisfying when you make the connection between the victim and the suspect, and it's kind of neat when you find something that nobody else ever thought of doing. General unknowns are a lot of fun, too, because they're a big challenge: what is it, where did it come from, and you try to identify a complete unknown, because it could be anything in the world that could be used as evidence. So, it's always a big challenge. I like the puzzle, the mystery of trying to figure the things out. Typically what we do is we get a sample, and we take just a few grams on the spatula, and we burn it. That would be a positive flame test, because it goes with a flash, it does that hissing sound, and it gives off a puff of white smoke. That would be a characteristic of black powder. Some explosives also burn but black powder has these distinctive burn characteristics that people can identify...from the way it reacts with the flame you can tell, and of course, under the microscope they are very different."

Melissa Smrz—The chemistry of DNA—Unit 8.3

"The foundation of DNA, when you go to molecular biology or to molecular biochemistry, obviously has its basic roots in chemistry. Acid-base relationships, protein chemistry, all these kinds of things, which typically are found in biochemistry but you still have to know acid-base reactions and things like that, are from chemistry."

Dr. Laurie Geller—Understanding environmental chemistry—Unit 8.6

"Now, when you're talking about chemical bonds' strength, you can discuss that it is not an abstract idea but this really matters in terms of environmental science. That helps you figure out how long a polluting molecule will hang around in the environment, whether or not it will be broken down in the atmosphere or not. When you talk about chemical kinetics, when you talk about how fast reactions occur between different types of molecules, you need to know that in order to figure out whether or not certain processes in the atmosphere are going to occur."

Quotes, cont'd.

And it doesn't have to be general big environmental ideas, it's just as simple to realize that it is basically chemistry that's holding this table together. Knowing about the bonds, and arrangement of the atoms, is what allows us to have solid surfaces to work on. Everything in your daily life rests on chemistry."

Prof. Richard Wool—Cooperation among scientists—Unit 8.6

"When we made the first tractors from genetically engineered soybeans the chemists couldn't do that—I, by myself, couldn't do that. We have to bring to the table all of the people who contribute to the different parts of the creative puzzle. You have, sitting around the table, genetic engineers, food scientists, micro-biologists who understand biodegradation processes, composite manufacturing people, who would not let anything above a certain viscosity come into the room, the chemists who must handle all of the connectivity issues, the manufacturing chemical engineers who understand the chemical reactions, all of these people, need to come to the table. And that's interesting, because when that happens, not only has each one a different part of the puzzle to contribute, but they also have a different way of interpreting how you think."

Dr. J. Craig Venter—Scientific literacy at an early age—Unit 8.6

"We've had third grade clusters coming through our institute lab, to get trained and isolate DNA. They actually cut it with restriction enzymes, they do experiments that I only learned to do as a professor, because it is a field that didn't exist before. I think that kids have a real fascination with that field, not that the technique was so complicated. We gave them a choice of isolating DNA from lettuce or from hamburger, and they chose hamburger. Then, at the end of the class one of the boys wanted to take the DNA home, and I asked what he wanted to do with it, and he said that he wanted to go home and clone a cow. The fundamental understanding of pre-teens is pretty amazing, so if our educational system improves to that level, quite often students who go into high school have wonderful contacts to place this information."

Prof. Terry Collins—Relating chemistry to modern life—Unit 8.6

"Young people are very idealistic. They want to think that the things that they do in the future are positive, and God bless them for it.... If we can't relate what we do in chemistry for the good of the people on the planet and the other species on the planet, I think that we have got a problem—that we are going to attract less and less of the greatly talented young people to the field of chemistry. That's a vicious cycle effect that doesn't happen because we really need outstanding chemists to have a sustainable civilization. I think sustainability is the biggest single idea for universities, and by implication for high schools, for the next 100 years."

Students' Ideas

About Chemistry

"It's a good thing to study chemistry because it's the background of all of sciences."

"In any science you really can't say: Oh, I'm studying about this, because you're studying a little bit of chemistry, a little bit of this, there's so much you do, you can't study just one thing, or else you are limiting yourself, extremely."

"It's such a basic part of our lives. It's just something that everybody needs to know, everybody thinks that it's magic that drives the cars. The copier works because it's just chemical reactions."

"It's how we explain our world; it's how we see things. I think it's good for everyone to know this."

Teachers' Forum

How To Teach Chemistry—Unit 8.6

Dr. Leslie Pierce—"Because all students in our system take chemistry, that means every student in Edison High School is going to need a chemistry credit. Then, we had an interest in giving some serious consideration to the way we taught chemistry."

Veatta Berry—"We had to rewrite and take all units and smash them together, and come up with something cohesive for the entire semester."

Quotes, cont'd.

Caryn Galatis—"We were going over all documentation and sort of decided at that point six themes that ran through chemistry, no matter what we were talking about, or what concept we were talking about: elements and the periodic table, compounds and bonding, kinetic theory, the mole and stoichiometry, chemical reactions and solutions. And that was the inspiration for organizing the units around those six threads that run through. We just started arguing what those themes were going to be and we decided that we would approach information related to these topics, in every unit we did. By doing the major themes at the same time together with each other, the kids learn it in an interrelated manner. So they are not asked to make the connections, they are making them as they learn the material, so the connections are there and they are solid."

Dr. Leslie Pierce—"As you're doing a little bit of solutions, a little bit of mole relationships and a little bit of periodicity, all at the same time."

Caryn Galatis—"In the first three units it does, it seems like such a model. Try to see how kids make the connections. Somewhere between the third and the fourth unit, it dawned on me one day, as I was with a group of kids trying to solve some stoichiometry problems, that these kids are asking me questions and having discussions with me that I couldn't get them to at the end of the course, before."

Training Teachers for the New World—Unit 8.5

Irene Walsh—"And if people want to become chemistry teachers, they need to have the ability to take something and break it down into a way of layering it, and look at the simple essence of it, and building up from there. Because just like you can't have somebody run a kilometer race if they are not trained, you've got them thinking in different sorts of ways."

Caryn Galatis—"The hardest thing is, twenty years ago, I was obviously trained in the traditional way, I don't have an educational degree, I have a chemical degree, it has been really hard. The benefit I had was that I was working with a group of colleagues who were all of bright mind and had the same intent to go and find the everyday experience, to go out and find the everyday connections to the real world. To try to find the stuff to bring to the classroom and relate it to kids, has been really really hard because there are no sources for a teacher to go to and find it, and just use it."

Examples From Teaching—Unit 8.6

Caryn Galatis—"What we had to do was to keep the rigor of chemistry but make it more real to them. And we do so many of our labs which are basically with household-type materials. Yes, you could teach almost a full chemistry course not having to ever order from a chemical supply catalog. With a few pieces of equipment, you could do a lot of really major chemistry: most of our labs are now oriented towards common household materials, we don't have an enormous chemical supply budget anymore. And that really ties the kids in too, because it's stuff they see every day."

Lisa Morine—"My kids like stories. Like we talked about the gas in the Nike air bubble, the sulfur hexafluoride, and how they needed to change it into nitrogen because it's poisonous. And they just love it when you tie it to something, because a lot of them wear those, that, they do every day."

Caryn Galatis—"I had bought the Road Wing Star as it first came out as a pre-production model...and the problem was that it kept blowing head gaskets. It has an aluminum cast engine that has steel bolts holding the head gaskets together, that expanded and contracted. They always asked what happened to my car and we kept talking about it in class, so I got to it a little bit early in the year, but now I talk about it every year and we go through it, because it was a big engineering mistake, that cost the company tons of money. And these things come up all the time, and anytime you can use an example like that, the kids understand it. My kids are starting to drive and this is near their hearts. And the expansion of metals is indeed a huge problem."

Tom Pratuch—"Once that link is established through the wallet, it makes it a point of interest. The ability to discriminate why to buy or choose something or what does a claim mean is important. A favorite of mine is organic and chemical-free advertisements, followed closely by why all those saturated fats have no polyenes in them and vice versa."