Dr. Moon's method: teaching the joy of scientific discovery

by Robert McLaughlin

The author worked closely with Dr. Robert Moon for four years and was his laboratory assistant at a children's summer camp in New York and Virginia in 1984, 1985, and 1986. McLaughlin is currently an international telecommunications consultant based in Canada, and is co-author of two books, Fix Your Own PC *and* Troubleshooting Your Lan. *This report on Dr. Moon and his pedagogy is based on an interview conducted by Susan Welsh.*

The first thing to understand, is that Bob Moon wasn't really teaching physics. If you had a class of 20 kids and one kid comprehended everything that happened, you'd probably be doing really well. You teach a class in physics, and you're hoping to improve, overall, the students' understanding of what physics *is*. More important, Moon thought, was to provide a way for students to understand that they can actually comprehend things, and that there are a lot of important issues to deal with in life, and that sometimes the scientific method will help you out. The cornerstone of Moon's life was belief in God and in the scientific method. That was it.

The discussions between him and the students would be half about the scientific material, and half about life. As far as he was concerned, if they learned some lessons about life from this old man, that was far more important than if they walked out of there and understood what a volt was.

The kids developed a lot of respect for him as a human being, and some of them, because of their admiration and love for him, tried to figure out what made him tick.

For him, the most important thing, since he was in his early 70s at the time, was not the next great experiment or the next scientific discovery, but laying the foundations for the people who would follow him. I think he had been thinking about what was going to come after him for a long time, because the series of classes that he did had started at the University of Chicago in the early 1950s, with advanced high school students. The University of Chicago has a summer program where advanced high school science students are brought in with their teacher and trained in various kinds of experiments that they could do in a high school. He ran that program for a long time. They did Ampère's experiments, which is what we did at camp, and Cavendish's experiments.

The Ampère experiments

They are not really hard experiments, that's the beauty of them. It is very obvious what is going on. They are crucial experiments, in the sense that they changed the way the scientific community thought about a problem in a very fundamental way. But they're all experiments that were done in the late 1700s or early 1800s, which means that anybody who's clever could do these things in their kitchen nowadays. They're not particularly expensive experiments—although they're not particularly cheap either. Ampère's experiments will cost you, if you've got access to a machine shop, a couple of thousand dollars. A couple of thousand dollars these days for four science classes is not really that bad—$500 a class. The problem is that things like brass, copper, and batteries are not cheap.

I had to scour the hardware stores of Loudoun County, Virginia to find the things we needed—or things I could substitute. I would come back with them, and Bob Moon would say, "What the hell is this?" One time he wanted some copper, and the best I could do was copper flashing. It took me three days to find what we needed, which was a piece of copper about four inches long. The man in the hardware store wouldn't sell me a piece of copper that small. The smallest he would sell me was a yard length of copper flashing, which was $40. We needed brass rods: The only brass rods I could find in the county were threaded, so we had to take all the threads off the rods first, in order to be able to use them.

The point was to have the students build the apparatus from scratch. For half of Ampère's experiments, doing it from scratch is no problem, because they involve things like sticking a wire in front of a compass and seeing the compass move. It's the final experiment which is the one that proves the relationship between magnetic intensity and current. That is, when you increase the current, the magnetic field goes up as a square, and how intense the magnetic field is does not depend upon the geometry of the wires that make the field.

This apparatus basically is a big wooden frame with a couple of coils, and inside these coils is a little coil. These things make a magnetic field, and as these are interacting, this twists, and the device measures how much twist there is, and tells you what the force is. Since the students had to

Moon and his assistant, Robert McLaughlin (center), work with children at camp. In the rear of the photo, Moon is instructing a group on the use of the lathe.

make it from scratch, we had to buy lumber to make the frame. They had to wind the coils. You have to have bearings and things like that, and because magnetic fields are involved, they have to be brass bearings, and because you want the students to understand what's going on, you have the students make the brass bearings.

We had a lathe, a drill press, some hammers. A lathe is a very intense machine. The equipment you need to make a lathe do what you want to do, costs a few thousand dollars. But it's actually very straightforward. There are a lot of people with metal lathes and drill presses in their garages. Anybody who hot-rods cars could do this.

That's where Moon learned it. When he was five, he fixed his father's car when it broke down. By the time he was nine, he had his own garage, and when he was 12, somebody tried to arrest the owner of Moon's Garage for employing child labor. He was quite proud of that garage. In those days, he'd take almost every part of a car, take it apart, retool it, work it with a lathe and a drill press, put it back together, and that's how you'd repair the car. You couldn't call somebody up and get the spare parts. Very rarely could you get spare parts. And a lot of the parts in the cars were hand made, so there *weren't* any spare parts. Every carburetor was different. So you had to retool the carburetor. That's where he learned how to machine.

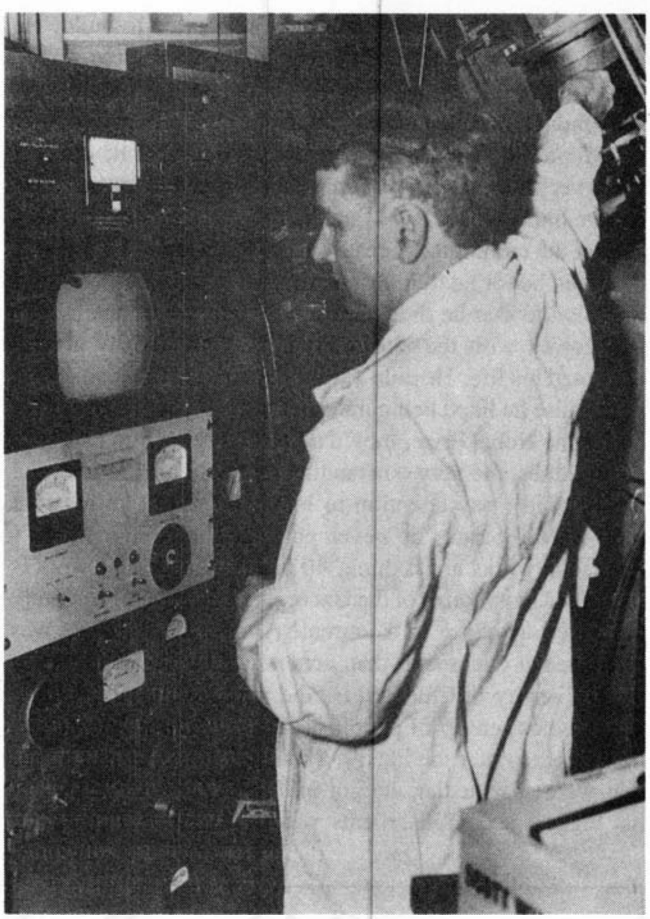
The class we were teaching at camp was very advanced. There are some questions about the appropriateness of it for the age group. It's impossible to do any crucial experiment in physics isolated by itself, and have people understand everything that's going on. As a teacher, you sometimes have to say, "Look, you won't understand everything that's going on. Don't worry about it. What's important is that you grasp the big picture, and in time the pieces will fall in." And that was the approach we took.

If one took it that the point of the class was to turn out people who understood the point of Ampère's experiments, then we failed. The point was, we were trying to turn out people who understood what went in to doing an experiment in physics—the planning for it, designing it, making the pieces, trying to get a glimmer of how an individual who did a great thing went about doing a great thing. In that, we were successful. And that was really what we were after. It was not important to us whether they understood what an amp was or what a volt was. What was important to us was that they took a pile of wire, a pile of lumber, a pile of brass, and turned it into something that worked, and realized, "Yeah, I can do things."

Moon spent a lot of time explaining to the children how he looked at the world, trying to make sure that they understood that everybody has gifts, everybody has different abilities. It's your job to know yourself. It's your job to employ those gifts and abilities that God gave you, to make the world better. And that's your responsibility. It doesn't particularly matter what they are, and you shouldn't be ashamed if you're not one of the great personages of history. There's nothing wrong with having a nice, simple, plain life. Just as long as, when all is said and done, the world is a little better because of your life. He spent a lot of time going over that again, and again, and again, trying to communicate that with personal recollections, little stories from his childhood.

You don't normally do experiments like this in a high school physics class, or even in college. In engineering schools, a mechanical engineer will end up with maybe two semesters in a machine shop, which is why, when you come out with your engineering degree, you spend another five years really learning how to be an engineer. This is true in college, too. If you take normal undergraduate physics, you won't go anywhere near any of this stuff until you hit graduate school.

In schools, this mostly has to do with the fact that it's really hard to get 1) the money, 2) the material, and 3) the cooperation among the departments. The whole problem with schools is the compartmentalization. That was Bob Moon's biggest complaint: The physics people don't talk to the mathematicians.



Robert Moon in the 1940s viewing the scanning X-ray system he designed—a system which led later to the development of the CAT scanner. Shown are the control panel, storage system, and viewing kinescope.

Moon's experimental method

Moon had maybe four major interests in physics. As time went on, he would want to do an experiment—not so much to prove or disprove a theory, but experiments to find out what nature was doing, which are the most fundamental kind of experiments. He'd come up with an idea and say, "I think nature does this." And then he'd want to do an experiment.

But none of the equipment to do the experiment existed. He did experiments in radioactivity, for example, but to do so he had to detect very minute quantities of neutrons, and people told him he couldn't do it, because there was no equipment that could do it. So he invented a funky kind of detector, in order to do his experiment. Every one of the experiments that he did in his lifetime, as a professional physicist, was of that caliber. Every one of them was, "I want to do this"—and then a process of invention of gizmos in order for him to do the experiment. What he did for the Manhattan Project was to invent the detectors. He became renowned for being able to invent a gizmo that would let somebody do something that hitherto everybody thought was impossible.

Moon liked controlled chaos. Very infrequently do you ever really know what you're doing! In science in particular, a lot of times you have half an idea in your head, and you spend a lot of time trying to turn that half an idea into a whole idea. A lot of times the half-idea you started out with turns out to be completely wrong, and you stumble into something completely different. You don't know what you're doing, you are in a state of chaos. So if you're going to do science, get used to the idea that you really don't know what you're doing most of the time. And if you did know what you were doing, you probably wouldn't be doing it. You don't do a crucial experiment if you know what the result is; because if you know what the result is, it's not a crucial experiment. If you don't know what the result of the experiment is, and nobody's ever built the apparatus before, you don't know whether the apparatus is really working or not. You don't know whether you designed it right or not. You don't even know what kind of physical principles you're talking about while you're doing it.

Albert Einstein only did one experiment in his life. He came out with a value for this experiment, and it was off by 2 from what was expected, and he was quite happy about it. Why was he happy? Because it told him something new about the electron. He wasn't an experimentalist. He didn't know much about how to build the thing he wanted to build. He didn't know what the result was going to be. He wasn't sure it was going to work to start with. But he knew it was something he wanted to find out about.

Moon didn't tell a lot of people about what he did. He was a very humble man. There was a committee formed once to give him a Nobel Prize, and he did everything he could to disrupt the committee, because he didn't want it. He thought it was an honor he didn't deserve, that it would bring things into his life that he didn't want. He didn't want the money that comes with the Nobel Prize, because money always disrupted his life. He didn't want the acclaim that came with it, because he liked being the quiet little guy in the corner. If he got the Nobel Prize, they'd all be bothering him.

He did some very outstanding things in his lifetime, but if you didn't pay attention to him, you didn't know what they were, because he never published anything. Moon's published works are, I think, 40 pages. Most of his work is published in bulletins of the University of Chicago. He rarely published anything in a journal. Almost all his work was published as documents that were issued by the laboratory at the University of Chicago. He did that deliberately. Only a small, select group of people at any given time knew what he was up to, and he liked it that way. When he did things that were spectacular, he got into a lot of trouble. One of his biggest accomplishments was to design and build the University of Chicago cyclotron. He became very famous for all the things he invented, and spent four years going across the United States, teaching people how to use all these things—and was not able to get anything else done.

Moon's problem with graduate students was, they would go through high school and college and they would do experiments where they were told exactly what to do, step by step, and they'd get to the graduate level and wouldn't have a clue about how to plan out what they were going to do. Instead of acting as a thesis adviser, which would have meant setting them up in the corner of a lab, he ended up instructing them in how to deal with the fact that they didn't know all the details of what they were going to do, and how to deal with an unexpected result.

Not knowing exactly what is going on is not per se a bad thing. You have to build up a certain amount of confidence in yourself. You come up with ideas, you're not sure where they came from, they're very gray. But you have to have confidence in your ability to come up with these ideas, to be able to go forward with them. And there's no way to get that confidence other than starting with something small, and taking it forward. Otherwise, if everything's pre-packaged, you'll never, ever develop confidence. You might understand some principle. It might become clearer from the experiment. But it won't teach you anything about how to conduct your own experiments. That's what you have to learn.