



Problem Solving

Despite the fact that I have been teaching physics for over thirty years, I'm still uneasy about my approach and that of my colleagues to one aspect of teaching physics. When we talk to our friends in engineering whose students we are preparing for a more technical discipline or to the future employers of our students, we like to emphasize that along with all the good physics that is being taught, their students/employees are being trained in problem solving.

Oh, there are some attempts. In the introductory mechanics, we tell them to draw a picture, isolate the vectors, and resolve into components. Up to that point we do a pretty good job, but as the press of content mounts we try to cram everything we can into the introductory courses, so we can state that we brought our students into the twentieth century with a bit of quantum theory and "particle in a box."

But lost in this is the promise of producing problem solvers. What remains in the introductory courses are mainly *ad hoc* approaches to the material being taught. It tends to be a two-step process: (1) What's the phenomenon addressed in the problem? (2) What's the equation you need to answer the question? Some physics profs poke fun of students who use this approach, but they rarely give them anything better to work with. And in many cases, I must admit, nothing more is needed. Such problems force the student to think about the relationships between the physical quantities and compute a result. Nothing wrong with that. Then what's the problem? It ain't real problem solving. It is not the problem solving that can be transferred to situations that arise in optical engineering. It's more a set of operating instructions. ("To set the timer, push the Program button on the remote")

So where or when does real problem solving get taught? In many cases, nowhere and never. I related my own introduction to problem solving in a previous editorial when I described my first engineering job as a summer employee working for Rockwell ("Becoming an Engineer," March 2002). I was simply thrown into the situation and expected to produce. Although that approach

will work for some people, generally it is a poor way to develop the skills needed for a lifetime.

But it happens all the time. Many a novice physicist, electrical engineer, or mechanical engineer has been given an existing optical system and told to redesign it. He or she is expected to learn the concepts and approaches to the design on the job. The problem is that the only background they have to work from is based on their previous tasks—there is no structure upon which to build. What is needed is a grounding in the basic concepts, an understanding of the field, and a knowledge of the various methods of analyzing the different optical systems.

Where is technical problem solving taught these days? One of the most instructive sources can be found not in academia, but in the popular media. In America there is a program broadcast on National Public Radio (NPR) called "Car Talk." In most parts of the US it airs on Saturdays. It is a call-in program conducted by two brothers, Tom and Ray Magliozzi, MIT grads, who take questions from listeners on cars, car repair, and anything remotely related to transportation. What sets this show apart from any other show on the planet is that it demonstrates the problem solving process many times during each program.

The show is one of the most popular on NPR and exposes many people to the problem solving process. When listeners call in, they state their car problem and add any symptoms they think are relevant to the difficulty. Then the hosts ask them questions that might help to narrow the source of the problem. Theories are set forth. In some cases, they are discarded and new ones are proposed. In other instances, the caller is asked to make additional observations. Sometimes a decision tree (never called such on the program) is set up and a number of tests are suggested to narrow down the source of the problem. Even the solutions are sometimes presented as a series of choices. For example, a caller may be told that he can either get an indicator fixed for a large sum of money or put a piece of black tape over the light. For those who have never heard of "Car Talk" and for our overseas readers, you can hear the weekly show on the Web at <http://cartalk.cars.com/>. Be aware that you have to have a reasonable amount of bandwidth to listen.

What becomes apparent after listening to a few programs is that there is a standard approach to the solution

of these problems. First, the problem is stated and, if necessary, qualified (At stoplights? During hot weather? While going up a hill? . . .). Then the symptoms are described and, perhaps, again qualified. Theories are constructed and tested against the problem and the symptoms. If a single theory satisfies the tests, then a solution is proposed. Otherwise a decision tree is set up: "If this happens, see if this changes the symptoms, otherwise try this" Further, there is a ranking of priorities where there are multiple problems. Anything involving safety (braking, steering, etc.) is addressed first and all other issues take second place.

What is important about "Car Talk" is that listeners are exposed to about a dozen situations each week during which the process of problem solving (identification, description, theory construction, theory testing, solution tree generation) is demonstrated. In comparison to the "two-step" problems in our physics courses, these dilemmas present situations much closer to what an engineer will face at work. I sometimes wonder how many listeners pick up the strategies that are illustrated during the program and apply the process to their own problems.

One phase of problem solving that is left out is the research phase. In this case since the Brothers Magliozzi know almost everything about cars, this part of the process tends to be omitted. Some callers, who are problem solving, use them as their expert references.

However, they do add a step, which is sometimes omitted in real life problem solving—quality control. Occasionally there will be a segment called "Stump the Chumps," during which they will contact one of the former callers and see if their diagnosis was correct and if the problem was solved by their suggestions. On the whole, their performance is not perfect, but considering the entire process is conducted by telephone in a public forum, it's pretty good.

Although there is no call-in show for optical engineering, the problem of educating future professionals needs to be addressed. Those who are teaching students in the disciplines that feed our field have an obligation to provide more than just content. What is needed is a variety of experiences for undergraduates in our laboratories. One such program, which the School of Physics here at Georgia Tech participates in, is Research Experience for Undergraduates (REU) sponsored by the National Science

Foundation. It gives undergraduate students, usually rising seniors, ten weeks in a research lab during the summer. The rationale is that students who participate in such a program will be more likely to go on to graduate work. I don't know how well it works overall. At Tech it seems to have mixed results. A fair number would have gone on to graduate school in any case. One that I know of got out of physics altogether and went to music school!

One difficulty with any undergraduate training in a research lab is that the student, having no background in the field, is put to work as a programmer. It is the path of least resistance for some researchers and it can end up driving students away rather than attracting them to the field. But if a real effort is made to involve a student in the problems at hand, even if they can only contribute modestly, they will be engaged in work and any problems presented to them will be meaningful.

Teaching problem solving from a book or as a series of course exercises results in a sterile exercise. This is certainly true for optical design, which is a very specialized form of problem solving. It is only when a student, teacher, or engineer has to come to grips with the myriad options and restrictions provided by a real problem that the full multi-step solving process kicks in. Then the solver has to assess the problem and narrow the possibilities based on what they know and what they can find out. A far cry from the "two-step" physics problem. In addition to real problems, students need to see more than a few of them. For example, if the only problem a designer got was a lens design and he or she didn't have to contend with problems involving mechanical or thermal or cost constraints, the solutions would tend to be unrealistic or cumbersome.

There is no easy path to providing instruction and experience in teaching problem solving. It is a problem to be solved student by student and year by year just like the topic itself. But one of the things I suggest students do is to listen to how they do it on "Car Talk."

Donald C. O'Shea
Editor