From the Editor

Procedural Knowledge, Storm Doors, and Ragged Edges of Metal

A lot of the products we purchase require assembly once we take them out of the box. I have noticed that some people lay out all the parts and then try to put the product together, without reading the instructions. Others sit down and read through the instructions first, examine the parts, and then proceed. Yet others read the first step in the instructions, carry out that step, read the next step, and so on. There are probably other possibilities as well. My approach generally follows the second description.

I recently purchased a storm door. It came with a rather voluminous installation booklet. I read through the booklet, laid out the parts, and began. The hinges were to be attached to the door with sheet metal screws. In looking at the screws provided, the thickness of the metal into which they were to be threaded, and the diameter of the pilot hole, I decided that there was going to be trouble ahead. There was. I ruined the Phillips head on three of the screws. Knowing that steel and aluminum were dissimilar metals and could cause deteriorating electrolysis, I fretted about what kind of screw I should purchase to replace the originals.

With the hinges attached, I proceeded with the installation. I then discovered that the door would not clear the header piece. I went back to the instruction booklet and discovered that I had misinterpreted the procedural steps. Uncharacteristically, I had followed the words rather than the drawing. Three more broken screws, another trip to the home center, and I had it installed properly.

My neighbors know what I do. I have talked to them about the importance of developing technological literacy and problem solving skills, as well as my role in doing that. They also know that I was educated in an earlier era, in which I had developed a considerable amount of skill in the use of tools. My pride was devastated, for I was certain that my neighbors saw me install the door, remove it, then install it again. They knew that I had made a mistake. I considered doing the reinstallation after dark, when my neighborhood had gone to bed.

Then came the installation of the latch set. The manufacturer recommended the use of a wood cutting spade bit to cut through the thin aluminum sheet metal for the latch, to me an obvious example of misusing a tool. I knew what would happen if the spade bit was dull, so I sharpened it. Just the same, it produced a ragged looking hole. Though it ended up being covered by the latch assembly, I will always be able to recall what it looks like under there and that will bother me.

What should have been a rather straight-forward and rewarding installation, ended up being a complex, philosophical, and somewhat frustrating experience. I wondered if the do-it-yourself era has passed the average do-it-yourselfer. I also wondered if knowing what I know about materials and processes actually resulted in more anxiety about the job than would have been the case with the "average" homeowner.

When I started my early morning class the next day, I found a role reversal. I had prepared what I thought was an excellent, step-by-step procedure for setting up and using a computer-controlled router in the lab in which I teach. Yet, when I put it to use with students, I found that it fell short in several ways. For example, I discovered that there should be only one discrete instruction per written list item. Otherwise, students tend to overlook the later-occurring instructions in the item. They also tend to skip steps, especially when the list of steps is long. When I asked the students why they did not read the steps thoroughly, the answers they give were varied and did not lead me to any conclusions. What's more, when I asked those who had successfully gotten the computer-controlled router to perform properly, few had any idea of the concepts behind the procedural knowledge. They had little or no idea why the steps were performed, nor why they were performed in a particular order. They followed the steps like robots. I should have known this at the outset, for I had already reinvented these wheels or turned over these rocks many times before.

The reason for teaching the students how to use the router was to enable them to incorporate it into the process of solving technological problems. Yet using it demanded the following of prescribed steps and any departure from these steps would result in frustration for the students or even damage to the machine. Though the machine could be applied in creative ways, the actual use of the machine to achieve this creativity is rather routine. How to teach this sort of underlying procedural knowledge, when to teach it, and to what depth to teach it, has been a career long dilemma for me, and I am certain I am not alone. In earlier days, we could justify teaching to nearly any depth we wished, for one of the primary objectives was to teach skill in the use of tools. Those days are gone.

Consider two polar scenarios related to the foregoing—scenarios that I have described in the past. One is in teaching students about structures. Students might be given a set of materials, prescribed in a design brief, to build a structure that would hold the greatest amount of weight. In many situations I have observed in educational practice, the students are given little or no background instruction regarding how to solve the problem. In fact, they are expected to solve the problem with the knowledge with which they walked through the door to the class the day the problem was introduced. No explanation or experiences are provided to the student about how forces might be distributed, how gravity might interact with the structure, nor how the properties of the materials being used might determine the ultimate strength.

Once the structure is tested to determine how much weight it could hold, the results can often lead to erroneous conclusions by the students. For example, the elapsed time from when glue was applied to two pieces of material, and when the pieces were assembled, may have actually accounted for why the structure failed or did not fail, rather than the design itself. Likewise, a student who has the manual dexterity and skill in the use of hand tools will be able to create closer fitting joints than those who do not. The precision with which the structural members fit with one another may have been more important than the design. We may be inadvertently teaching "bad technology," akin to the misconceptions that result from "bad science" about which the science education community has been concerned for the past several decades. Students may have made cause-effect conclusions based upon the incorrect cause.

At the other extreme is the insistence that students learn so much prerequisite procedural knowledge and theory about a particular area of study that only a few can invest the calendar time necessary to enable them to solve technological problems. Others lose interest and give up.

One example of this scenario is in the area of electronics. Students of this subject often spend great amounts of time learning Ohm's Law and verifying its truth using power supplies and meters. They learn about alternating and direct current and how to convert the former into the latter. They learn about resistor color codes, and capacitive reactance. Too often, though, they may never reach the point where they can solve a technological problem using electronics unless they earn a degree in the subject.

Electronic experiment kits, intended primarily for elementary/middle school students, are available from Radio Shack and a variety of other sources. They come with a booklet that illustrates and describes how to connect an array of different electronic circuits—procedural knowledge. Though the children assembling these circuits likely have no idea of how they work, motivation comes from the practical application and the appeal to their senses. They connect a circuit for a buzzer that operates from a pushbutton switch. They connect a circuit that turns on a light when the room becomes dark. By combining the two, they can intuitively put together a circuit that turns on a buzzer (instead of a light) when the room becomes dark. They have solved a technological problem that they wanted to solve, and along with it came the excitement and motivation with which all of us in this field are familiar and uniquely bestowed. With guidance and more experience, the learner often becomes curious about how the circuit works. Practical application begets curiosity about the underlying theory.

I had roughed out this manuscript to this point and then I left town to participate in the annual conference of the Technology Education Association of Pennsylvania. Coincidentally, one of the keynote speakers at the conference was Iannois Mialoulis, President and Director of the Boston Museum of Science and former Dean of the College of Engineering at Tufts University. In his presentation he cited efforts that colleges of engineering have been mounting to try to retain students as engineering majors. He mentioned that traditional engineering programs have emphasized during the first two years of study almost exclusively the mathematical and scientific theories that undergird engineering. Very capable students were lost to other fields of study simply because they saw no reason or context for what they were studying relative to the field that they thought they were interested in pursuing for their career. They switched majors. In land grant universities, where I have spent the majority of my career, I can attest that technology education is one of the most likely alternative choices for a frustrated engineering major. Times are changing, though. Colleges of engineering are looking at how they can retain these students by providing interesting and challenging technological problem solving opportunities to them from the outset. Moreover, engineers are making connections to what is happening in K-12 education, often connecting with technology education in the process. Dr. Mialoulis mentioned that the engineering-technology education connection is ideal for two reasons. First, we have a wonderful record of doing effective hands-on activities with students. Second, we are worried—worried about how we can maintain our viability and expand our role in the overall educational enterprise.

So how do we make decisions about the proper proportion of time we spend on developing requisite procedural and theoretical knowledge on the one hand, and engagement in actually solving the problem on the other? As educators in this field we are constantly making these decisions, but upon what basis? Students need to have some background related to the problems we are asking them to solve. Otherwise they are dumbfounded and do not know where to start, wasting time in the process. But how far do we go before we let them be creative and when are they sufficiently prepared to engage in the thinking that is required to develop effective solutions to technological problems? When are they prepared to acquire the new knowledge they need to solve the problem at hand when they need it and through their own volition? Williams (2000) provides some very helpful suggestions. As is too frequently the conclusion to my editorial pieces, though, there is very little research to inform us and when we try to extend the findings in this regard from science or mathematics, the apple-orange comparison is often valid. Yet, the decisions we make have grave implications for the efficiency of our teaching practice and ultimately what our students are able to learn and our accountability to them.

The ragged edges of metal hidden under the latch assembly of my storm door and the electrolysis of those screws will continue to haunt me as I count sheep going over the fence in order to fall asleep at night. The sheep that occasionally hits the fence rail with his hoof, though, keeps waking me up. That sheep is the one that represents the requisite theory/procedural knowledge dilemma.

JEL

References

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Williams, P. J. (2000). Design: The only methodology of technology? *Journal of Technology Education*, *11*(2), 48-60.