OISE/UT LIBRARY
3 0005 03237374 1

TEACHING FOR DEEP UNDERSTANDING

What Every Educator Should Know

KENNETH LEITHWOOD
PAT McADIE
NINA BASCIA
ANNE RODRIGUE

370.1109
713
T253
2006
c.2

8

Understanding Technology

Carl Bereiter

When people talk about technology these days, they often refer only to recent, mainly digital, technology. But our lives are surrounded by technology, some of it very old, and much of it unnoticed. In this chapter, Carl Bereiter outlines an approach to understanding technology that will help equip students for full participation in a knowledge society.

1. Many think of technology as tools. How can teachers help students understand how these tools work?
2. How can teachers encourage their students to see that technology is a result of human thought?

If Benjamin Franklin were to reemerge on the street in a modern city, many things would of course amaze him. He would be puzzled by the number of people who appear to be carrying on conversations with little gadgets held up to their ears, and he would wonder about the vehicles that apparently move under their own power. But he would probably be most fascinated by technology he could understand, for instance, the varied means of people-powered locomotion—bicycles, Rollerblades, and skateboards. Any of these could have been produced in his own day, but he would quickly perceive that they all depend on other technology, such as the technologies that produce smooth sidewalks and streets, which make such conveyances practical. He would marvel at the tall buildings and would wonder how they were constructed, but, like most of us, he would be little aware of the vast amount of technology required to make such structures livable—the heating and air conditioning, the plumbing, the elevators, all of which needed to be specially devised to accommodate buildings of great height.

There are four aspects to an understanding of technology. One is technical: understanding how things work, understanding the engineering and design principles and the bodies of scientific knowledge underlying them. The second is understanding the big picture in its historical and social scientific aspects: understanding technology's development over time and its social effects. The third, and probably the most challenging, is understanding technological thinking and developing the ability to practice it. The fourth aspect is critical and evaluative: understanding the intended and unintended consequences of technology and weighing alternatives. All are important. Although these aspects are interrelated, a sequential dependency needs to be honored: The first kind of understanding facilitates the second, the first two facilitate the third, and the first three kinds of understanding are an important basis for the fourth. Indeed, one of the challenges for technology education is to overcome the kind of sophomoric criticism that reflects ignorance of the technology being criticized, a narrow and ahistorical perspective, and a stereotyped conception of technological thinking.

We now briefly consider ends and means with respect to the four aspects of understanding.

UNDERSTANDING HOW THINGS WORK

There was a time when mechanically inclined people could acquire a fairly deep understanding of the workings of their automobiles and could extend their knowledge by tinkering. That is no longer the case. Like many other common devices, automobiles have become forbiddingly complex in their inner workings, and tinkering is liable to produce unfortunate results. It is not only working devices that have become too complex for nonspecialists to understand but also materials and processes. With no possibility of developing an understanding of all the technology that surrounds their students, educators must decide what, if anything, is worth studying in depth.

Priorities for understanding, it should be noted, are different from priorities for practical knowledge. The most important practical knowledge of technology is that which will help students get along better in their daily lives. The most important technological understandings, we suggest, are those that have maximum potential for demystifying the built environment. Accordingly, the design of a curriculum for technological understanding ought to be grounded in research on what students actually find most mystifying in the technology surrounding them. However, identifying the maximally demystifying concepts is a step beyond, one that cannot be derived directly from such research. Students may wonder how cell phones work, but a direct explanation is likely to leave unexplained how radio transmissions spreading out into the atmosphere get captured

The most important technological understandings, we suggest, are those that have maximum potential for demystifying the built environment.

and converted back into intelligible signals. Understanding that will serve to demystify not only cell phones but radios, television transmission, and wireless Internet connections.

Other technology principles that have widespread explanatory power are:

- *Error-nulling feedback,* as involved in everything from the centrifugal speed governor on a steam engine to the servomotors on a robot arm
- *Data (digital and analog),* basic to understanding varied types of information technology
- *Switches,* as represented in everything from the common light switch to the transistor
- *Properties of materials*—not a single principle but a range of ways in which natural and manufactured materials meet various needs; for instance, how plastics can be made harder than steel

Many other principles could serve, depending on what research shows to be most mystifying to students of various ages.

UNDERSTANDING THE BIG PICTURE

Historical study should lay to rest the idea that technology is something of recent origin and mainly the product of large American corporations. During the Middle Ages in Europe, when science and mathematics were stagnating, technology was moving ahead, largely through the creative efforts of artisans. During the same period, China was experiencing a veritable golden age of technological creativity. We do not suggest, however, that the history of technology should be taught as a separate subject or branch of history. Instead, it is best understood in the broader context of cultural history. Students will see how Late Stone Age technology gave rise to both intertribal trade and intertribal warfare. They will see how agricultural technology yielded food exports that made cities possible and the revolutionary cultural changes that followed from that. And they will see how steam power and mechanization made possible the growth of modern industries and, by reducing the need for farm labor, provided the workers such industries required. In all these cases, furthermore, the social changes interacted with technological changes, each spurring the other.

IMPLICATIONS FOR TEACHING

Understanding technology is advanced by . . .

1. Understanding how things work
2. Understanding the big picture
3. Understanding technological thinking
4. Critical understanding of technology

An advantage of historical study is that the older technologies are easier for students to understand, thus contributing to demystification. The origins of ancient technologies are usually unknown and open to speculation (there have, for instance, been a number of theories about the invention of the wheel). But from an educational viewpoint, this speculative character can be an asset: Students can play the game, too, and thus engage in what we discuss next as technological thinking.

Historical study should lay to rest the idea that technology is something of recent origin and mainly the product of large American corporations.

Technology's social effects have sometimes been profound yet remarkably unpredictable. Did anyone predict the drastic social changes brought about by the automobile? Or television? Has the computer had effects of comparable magnitude—or will it? Investigating questions like these should bring students to an informed consideration of social aspects of technology. Other questions can broaden their understanding. Why do some technologies catch on and others fail to do so? Are the young always the most ready to take up new technology? What does this imply for an aging population? How justified is the belief that technological barriers will always eventually be overcome?

UNDERSTANDING TECHNOLOGICAL THINKING

Scientific thinking and technological thinking are both characterized by systematic, sustained efforts at idea improvement. Scientific thinking, however, has been extensively examined by philosophers and behavioral scientists, whereas technological thinking has received much less attention. Given that there is little agreement on whether such a thing as scientific method actually exists, it would be presumptuous to suggest that there is a teachable technological method. Students could, however, profit from investigating the stories of major technological achievements, how they came about, and the individual and collective thinking that went into them. Fascinating stories that have much to teach beyond the bare technological bones are those of Watt and the steam engine, the Wright brothers versus Santos-Dumont as contenders for first credit in heavier-than-air flight, Canada's Avro Arrow, and the Macintosh computer.

Besides studying how others thought their way to technological innovations, students should themselves engage in the essential activity of sustained idea improvement. Suggesting how some device or computer application could be improved is a common exercise in creative thinking, but students need to appreciate that this is only a first step, and often the easiest step in technological thinking. They need to work on design improvements that can be carried forward through research that identifies possibilities and obstacles and through further thinking that builds on this knowledge. At least some of their work should involve actual construction, testing, and further improvement of technology, using design challenges such as those coming out of the Learning Science by Design project (http://www.cc.gatech.edu/edutech/projects/lbdview.html).

> Besides studying how others thought their way to technological innovations, students should themselves engage in the essential activity of sustained idea improvement.

CRITICAL UNDERSTANDING OF TECHNOLOGY

Students are bombarded with advertising aimed at creating uncritical acceptance and an urgent demand for the latest technology. Little wonder that some students react with equally uncritical rejection, amounting to a general cynicism about technological progress. It is true that technological solutions to problems frequently create new and unforeseen problems, which are sometimes worse than the

By demystifying technology, we free students of the ignorance that treats technology as magic and the fearfulness that often seems to lie behind the more sweeping condemnations of technology.

original problems. Critical understanding starts with the recognition that this is true of action of all kinds, not just technologically based action, and is typically true of inaction as well.

Probably the best protection against both gullibility and cynicism is a solid grounding in the first three aspects of understanding. By demystifying technology, we free students of the ignorance that treats technology as magic and the fearfulness that often seems to lie behind the more sweeping condemnations of technology. A global historical view will impress students that many of humanity's greatest achievements have been technological, but it will also impress them with the importance of social progress and the magnitude of problems that technology has not solved. And, of course, the issues raised in connection with the social science of technology lead directly into critical analysis of innovations. Perhaps the biggest gain, however, will come from the students' developing a feeling for and some competence in technological thinking. In this way, they will see technology as a result of human thought—thought of which they themselves are capable and thought which, like all human thought, is susceptible to error and always open to improvement. They will also be less likely to be led astray by the demonizing of technology developers and by such epithets as technical rationality. By gaining a fuller understanding of such difficult issues as genetic modification and control of greenhouse gases, students will be better able to exercise the kind of judgment required for full participation in a knowledge society.