

## A Plea for Spatial Literacy

### Section: POINT OF VIEW

Some years ago, when my younger child was about 5 years old, a friend of mine was pregnant. Because she was having premature contractions, she was not supposed to exert herself too much, so shopping for baby supplies was difficult for her. I offered to lend her our old crib, which had been dismantled and stored in our attic.

My husband and I took the components to her house, assuming it would be a snap to reassemble the crib. After all, we had once put it together (albeit with written instructions that were now lost), had used it for years, and had later taken it apart. As it turned out, making the movable side actually move up and down proved impossible. That is, impossible until my friend — who perhaps not coincidentally has a bachelor's degree from MIT — came slowly upstairs, looked over the components briefly, and said, "Let's put that here, and turn this thingummy that way. ..."

You get the idea. A minute or so later, the crib side went smoothly up and down.

Spatial thinking is a challenge to many of us. We lose our car in a parking lot, give bad directions, or fail to put furniture together, even if we haven't lost the instructions. Yet we don't see our difficulties as a major problem for society. Americans have historically considered spatial thinking less important than the basics of reading, writing, and arithmetic, and not even as crucial as science, social studies, and some other components of the average school curriculum.

A recent report from the National Research Council makes the case that spatial literacy is indeed important. In *Learning to Think Spatially*, a study group chaired by Roger M. Downs of Pennsylvania State University states that "without explicit attention to [spatial thinking], we cannot meet our responsibility for equipping the next generation of students for life and work in the 21st century."

Downs and the other members of his group argue, with a wealth of examples, that spatial skills are more important in everyday life and at work than we may think at first blush. Consider the following tasks that might arise on a fairly typical day: packing a car trunk, replacing a flat tire, or finding the most efficient route among stores in a shopping center. All those activities rely on spatial thinking.

More ominously, consider the task of installing a child-safety seat in a car. Safety experts estimate that as many as 94 percent of such seats may be improperly installed, raising the risk of death and injury to infants and young children.

Spatial thinking also helps us think about domains that are not obviously spatial. Spatial metaphors and diagrams can be used to understand ordered relations (like the ranking of countries by population in different parts of the world) or complex hierarchical relations (like which species of mammals are most closely related). Venn diagrams can be used to solve problems in logic: The overlapping circles make clear the relations or intersections among subsets.

Maps do more than just show us where to go. They become tools for thinking when they display the distribution of variables such as population density, or natural and economic resources, and relate variables to each other. One of the most famous stories in epidemiology concerns the 19th-century map prepared by a London physician, John Snow, of a cholera epidemic. At the time, nobody knew how cholera spread. Snow's

map plotted the locations of water pumps and of cholera cases, revealing how cases clustered around one particular pump that turned out to be contaminated.

A critically important application of spatial thinking is in science, technology, engineering, and mathematics, called the STEM disciplines. The recent National Research Council report opens with the tale of one of the most significant accomplishments of 20th-century science — James Watson and Francis Crick's discovery of the structure of DNA. Fitting a three-dimensional spatial model to the known facts, including Rosalind Franklin's two-dimensional images, was a central part of that discovery.

Spatial thinking provides unique insights in various STEM disciplines, allowing a geoscientist to visualize the processes involved in the earth's formation, an engineer to anticipate how various physical forces may affect the design of a structure, or a neurosurgeon to use an MRI image to plan a brain operation. Progress and performance in those and other fields is thus strongly tied to improving people's ability to reason about spatial configurations and their properties. In addition, simply to be an informed citizen in the 21st century, each of us should be able to understand spatial abstractions and visualizations, including graphs, diagrams, and the new generation of complex images generated by satellites, probes within the human body, and so on.

Furthermore, spatial thinking is important in debates about equality of opportunity for women and people from poor families. When Lawrence H. Summers speculated that women were underrepresented on the science faculty at Harvard University due to basic differences between the sexes in cognitive abilities, he probably had spatial — as well as mathematical — thinking in mind. In addition, he appears to have thought that any such differences are biologically determined and immutable.

The evidence for sex differences in spatial thinking is pretty strong, as the new NRC report notes. Recently colleagues and I also found differences based on socioeconomic status, beginning as early as second grade. Children from families with below-average income do worse than children from households with average or above-average income at tasks that involve map interpretation and the mental manipulation of shapes. Intriguingly, however, gender differences exist in the middle- and upper-income groups, but not between poor boys and girls. That suggests that environment may play a role in sex differences.

Summers was wrong in his implicit assumption that nothing can be done about the differences we see in spatial thinking. Increasing evidence shows that we could do a much better job of teaching spatial-thinking skills. Even people who are proficient could be better at spatial thinking.

Some time ago, I collaborated on a meta-analysis of studies of spatial training done through the 1980s. My colleagues and I found very clear improvements in subjects' spatial ability, which were — as one would expect — more significant the longer and more thorough the subjects' training was. Later research supported that conclusion.

Studies have shown that children in elementary school improve their spatial thinking more when they are in school than they do when they are on vacation, and that various educational techniques can help children learn spatial tasks. Research that I collaborated on demonstrated that undergraduates who had prolonged practice or training on mental rotation were able to rotate mental images better for several months after the training, and also did better on other spatial tasks — an effect that has rarely been observed with

less prolonged training. The effects were significant, and far larger than the typical effects of sex difference.

A new meta-analysis that I participated in took account of the many studies completed in the past 15 years. The new analysis shows that we can substantially improve subjects' spatial skill through academic course work, practice on specific tasks, and even playing computer games. Though such games sometimes seem to be a waste of time, many require players to keep track of where they are, and where other objects are or will be.

So we know that spatial cognition is malleable, and that spatial thinking can be improved by effective technology and education. But as the NRC report points out, we still don't know exactly how to infuse spatial thinking throughout the curriculum, and how to use new technologies like geographic-information systems, especially with young children.

What kinds of teaching best support spatial learning? Do different kinds work better at different ages, at different socioeconomic levels, or for women and men? We need a firmer theoretical understanding of spatial learning and intelligence, and scientists and educators should work closely together on efforts to enhance spatial thinking. Better teaching should not only improve students' spatial functioning in general, but also reduce the differences related to gender and socioeconomic status that keep some people from fully participating in our technological society.

Spatial literacy is as important a goal as traditional literacy is. We need to invest our resources and efforts accordingly.

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