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Book review

Committee on "Support for Thinking Spatially: The Incorporation of Geographic Information Science Across the K–12 Curriculum," the National Research Council, Learning to Think Spatially. The National Academies Press, Washington, DC (2006). 332pp., $49.95 (pbk.), ISBN 0-309-09208-6 (pbk.), ISBN 0-309-53191-8 (PDF)

The Committee on "Support for Thinking Spatially: The Incorporation of Geographic Information Science Across the K–12 Curriculum" was formed on the basis of a proposal to the National Research Council of the US National Academies of Science and of Engineering, and the Institute of Medicine. Its members, and the primary authors of this book, were a multi-disciplinary group of 14 members (Chaired by Roger M. Downs of Pennsylvania State University) that included geographers and other geoscientists, physicists, psychologists, and education researchers.

This is a very important book with an overdue message that is largely valid and very significant in its implications. In brief, the book's thesis is that spatial thinking is critically important to performance in a variety of academic and applied fields, but its coverage in the US school curricula of Kindergarten to 12th grade (K–12) is incomplete, spotty, and lacking in integration across areas. These claims fuel the committee's call for educational standards in spatial thinking. They are right—spatiality is ubiquitous in our world, in our activities, and in our minds. Spatial thinking is highly functional, both personally and professionally. And spatial thinking has been given inadequate attention, if not woefully ignored, both in education and research. Instead, relatively too much focus over the centuries has been on the power of the word and the power of the number. Everyone knows the three R's of education; this book proposes that there should be four R's. One might call them Reading, 'Riting, 'Rithmetic, and Räumliches Denken (German for "spatial thinking"; a bit awkward, but after all, German is the main language after English for spatial thinking research, and "Roomination" didn't quite cut it).

In addition to its call for educational standards and an explicit role for spatial thinking in the curriculum, the committee also concluded that the teaching of spatial thinking would benefit from incorporating computer technologies into the K–12 classroom, including especially (but not solely) geographic information systems (GIS). In fact, this was not so much a conclusion as an original premise of the committee:

> The [original] charge contained two questions that logically followed from the proposal title: How might current versions of GIS be incorporated into existing standards-based instruction in all knowledge domains across the school curriculum? How can cognitive developmental and educational theory be used to develop new versions of GIS that are age appropriate in their design and to implement new GIS curricula that are age appropriate in their scope and sequence? (pp. 229–230)

However, the committee came to see that the original charge called out for something more intellectually fundamental and thus more ambitious. Therefore, the eventual charge of the committee expanded from the original charge:

> After coming to appreciate the fundamental importance of spatial thinking and realizing that it was not just undersupported, but underappreciated, undervalued, and therefore underinstructed, the committee came to a new understanding of the charge. The two original questions…could be answered satisfactorily only after two additional questions were addressed, one about the need for spatial thinking and the other about the ways in which we learn to think spatially. (p. 230)

In my opinion, this was a wise choice indeed. It certainly made for a more interesting and important book. (Admittedly, some will see this as a bit of a pipe dream. There is money to be made on disseminating technology, and for-profit companies are not going to wait for academics to figure this all out before they promote their products to teachers and students.)

The book explores the concept of spatial thinking, which "is based on a constructive amalgam of three elements: concepts of space, tools of representation, and processes of reasoning" (p. 3). The book provides a nice discussion of spatial properties, relations, transformations, and manipulations. Unlike the psychometric and experimental literatures in psychology (about which some of the committee members are extremely conversant), the book gives spatial thinking a much broader and more inclusive treatment. For example, it distinguishes and relates internal and external spatial representations, and offers extended and fascinating discussions of spatial thinking in astronomy,

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geology, climatology, and geography. I think the book falls short insofar as it implies that spatial thinking, that spatiality itself, is equivalent across domains—that there is a singular "spatial thinking." Aside from their discussion of the traditional process components in spatial thinking (pattern recognition, relations, visualization, orientation, etc.), the authors hardly mention the real possibility that spaces at different scales and dimensionality involve at least partially distinct types of thinking, abilities, brain areas, and so on. Imagining the rotation of a small polygon in one's head is not the same thing as figuring out which direction to hike through the forest. Although this is not sorted out once and for all, there are logical and empirical reasons to consider it a viable research issue (see Hegarty, Montello, Richardson, Ishikawa, & Lovelace, 2006). To an important degree, I believe, space is not space is not space.

In the end, the committee is very forthright and detailed about the limitations of GIS as a support system for spatial thinking. To their credit, they explore not only various GISs (including products other than those of ESRI, who provided some financial support for this committee) but also software packages for the geosciences, CAD, graphing, and more (shockingly, no mention of the implications of Google Earth!). The book does not make a naive, unconditional call for GIS and other technologies in the classroom. "Taken alone, GIS is not the answer to the problem of teaching spatial thinking in American schools; however, it can play a significant role in an answer" (p. 8). More than once, the book even promotes the value of non-technological approaches to teaching spatial thinking (chalk anyone?). But the book clearly does push for incorporating technology into the classroom, and I suspect some readers may continue to question this techno-push. Obviously, one can ask whether its ulterior motive is profit generation and the creation of markets, now and in the future. A more substantive intellectual argument might question the book's claim that GIS can help support education in spatial thinking because GIS use requires spatial thinking. Neither GIS nor geography more broadly are exclusively spatial. They are thematic, temporal, and logical in nonspatial ways. The committee blurs the distinction between spatial and geographic to some extent. I have sometimes wondered if people who tout the role of spatial thinking in GIS, and GIS in K–12 education, are forgetting that much (most?) spatial thinking when using GIS is really just spatial perception (as in pattern recognition) and not spatial memory, inference, or reasoning. When I want to see the pattern resulting from overlaying two data themes, I don't do spatial thinking—I type or click "overlay" and see what results.

The committee assures us that technology can assist and extend cognition—that it "augments and enhances" thinking. They repeatedly emphasize that technology supports but does not substitute: "A support system does not replace the human process of thinking, automating it by means of a 'machine'" (p. 140). To me, this rang more like a proclamation than an empirical or logical argument. There are too many historical examples of technology, spatial and otherwise, replacing and thereby weakening human intellectual abilities. From students who use calculators in grade school not being able to add or multiply in their heads very well to people who can't spell very well because of their reliance on spellchecker programs, technology changes the way we think, frequently in a manner that one might call "infantilizing." Take the committee's own detailed example of the navigators of Micronesia in Box 6.1 (other technologically underdeveloped cultures possess or have possessed similar skills). Their amazing expertise, very little of which is "technological," includes a vast array of celestial route maps (of the mental variety), the interpretation of ocean swell and wave patterns, and a storehouse of knowledge about the appearance of the sky, bird species, and more. But no one these days believes that these amazing skills are part of some "innate primitive intelligence"—they are based on a culture of training, of practice, and of honing attention to particular details in the world. We modern (and post-modern) navigators of technologically developed cultures replace these intellectual abilities with technologies that do the cognitive work for us. I have collected stories that anecdotally document how GPS and related technologies have left people disturbingly ignorant of finding their way when the satellite reception goes down or the batteries run out. In fact, the committee provides an excellent list of "tensions that can lead to significant problems for learners and teachers" in the use of technological systems to support spatial thinking; for each of these tensions, "there is no simple resolution" (pp. 144–145). This list contradicts their otherwise self-assured, in places almost glib, embrace of the cognitive benefits of technology.

Besides its 11 chapters, the book has several appendices. The reader should not skip these, as they are quite good. I was particularly impressed by Appendix C on "Individual Differences in Spatial Thinking: The Effects of Age, Development, and Sex." This is really excellent and makes several critical points about a subject that nearly everyone finds irresistible—how and why do individuals and groups differ in their thinking? In this appendix, the committee eloquently recognizes that documenting differences, including the age and sex-related differences in both abilities and strategies that have reliably been found, leaves explanation—what causes the differences—quite ambiguous. They further emphasize that the existence of differences in no way precludes their alteration or attenuation. This is true even if the differences are genetically caused, a point that goes overlooked or misunderstood on a regular basis. Third, the committee emphasizes that difference on a particular task or skill does not necessarily apply to other domains, even related domains. "In short, a statement about differential abilities or strategies carries no implications that differences are inherent (the first point), fixed (the second point), or pervasive (the third point)" (p. 267). But the committee's wisdom doesn't stop there. "Differences among learners

may be considered either at the level of 'group differences' or at the level of 'individual differences'" (p. 267). Thus, the existence of group differences does not necessarily say much about individual differences. That would be stereotyping, which everyone knows is wrong. Finally, I laud the committee in this appendix for pointing out that even differences caused by experience could ultimately stem from innate differences in the proclivity to spend one's time doing something. People who are really skilled at something have spent a great deal of time doing it, and expertise at complex tasks doesn't come without the investment of time and effort. I have increasingly come to suspect that individual differences in skilled performance are linked strongly to individual differences in preferences and propensities to do certain things. Yes, Mozart was musically skilled. He also spent an incredible amount of time listening to music, playing it, and thinking about it, even by the age of 5.

In conclusion, this is an admirable, thought-provoking book that deserves wide readership. Even though I have some concerns about the book's arguments for GIS technologies in the K–12 curriculum, it has persuaded me more than anything I have ever read on the issue. Of course, a book like this, cobbled together by committee, may be expected to read in a disjointed manner. Knowing the work of most of the members of the committee, as well as knowing several of them personally, I thought I could frequently tell which section or which paragraph came from which author. So the book does read a little disjointedly and also has a little redundancy, but overall, the writing was pretty good. Someone, perhaps the committee chair, did a decent job of keeping the problems of committee writing tolerably modest.

One small pet peeve in conclusion: The book repeatedly refers to tasks that are difficult to learn as tasks for which "the learning curve is steep." This is a misleading, albeit common, figure of speech. Learning curves are found on graphs that show a reduction in errors or response times, or an increase in correct answers, over time. This means that easy, quickly learnable tasks will plot as steep curves on the graph, and hard tasks that take a long time to learn will plot as gradually sloping curves. I guess the mix-up stems from the metaphor of a steep cliff being difficult to get over.

References

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