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Real-World Knowledge through Real-World Maps: A Developmental Guide for Navigating the Educational Terrain

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It is perhaps unusual to insert an individual acknowledgment into a coauthored paper, but we have agreed that I (L.S.L.) might do so. I dedicate this article to the memory of Jim Blaut. For those readers familiar with the vituperative nature of our disagreements, particularly the exchange published in the 1997 volume of the *Annals of the Association of American Geographers,* this may seem surprising. But despite our diverging theoretical stances, we shared a deep concern for geography education. I have long admired Jim's seminal contributions to the study of young children's understanding of places and place representations and have profited profoundly from his work and even from his attacks. I am certain that I speak for many of us in saying that he is already deeply missed.

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Maps have real-world utility for activities of daily life and are critical for many disciplines. Here we discuss how educating children to use maps for navigation may enhance not only their wayfinding skills, but also their more general representational and spatial skills. After reviewing relevant developmental and educational research, we document the need for innovative educational curricula to meet the challenges of teaching map navigation within the school setting. We then describe the development and evaluation of one such curriculum—*Where Are We?* (*WAW?;* Kastens, 2000)—designed to simulate real-world map-navigation experience. We close by proposing five components that should be included when evaluating any developmentally motivated curriculum for teaching real-world knowledge, illustrating each component by reference to our ongoing *WAW?* evaluation research.

Developmental psychology is focused on the description and explanation of the myriad physical, cognitive, and socioemotional changes that occur in individuals from conception to death. In part, the motivation to study developmental psychology is like the motivation to study any academic discipline: We are simply curious. But in part, the motivation is practical: We believe that understanding individual development can help us to design successful educational environments.

The articles contained in this issue of *Developmental Review* focus on the contributions that developmental psychology can make to teaching ‘‘real-world knowledge.’’ We interpret this phrase to mean knowledge that is acquired in or used for everyday life. In some cultures, virtually all educational functions take place *in situ*, as when children learn to weave alongside family members or in apprenticeships (e.g., see Rogoff, 1990). In others, including contemporary cultures in the United States, most of the educational enterprise has shifted to schools. This shift poses many challenges. Skills that remain important may be overlooked in the formal school setting or may be difficult to teach within it. In our work, we are concerned with one example of this kind of knowledge that is also linked to a more literal interpretation of ‘‘real world.’’ Our focus is on not only acquiring knowledge *from* and *for* the real world: it is also on knowledge *of* the real world, that is, knowledge of the Earth on which we live.

One could, of course, subsume virtually every arena of human knowledge under this rubric. Earth contains the micro and macro environments of our biological, physical, and social worlds, and its study requires understanding the still greater universe in which Earth is embedded. Our focus is thus necessarily more limited: We consider educational programs designed to teach children how to use the artifacts that are humanity’s fundamental tool for representing information about our real world—maps.

Because map-related education in our schools takes place largely within the context of geography education, we begin by overviewing the way that geography education is currently conceptualized, noting in particular the centrality of maps within that conceptualization. We then briefly note maps’ roles in diverse disciplines and occupations, and their potential value for fostering children's representational and spatial skills more generally. We next explain the decision to focus our work on one particular use of maps, specifically, maps as tools for navigation. After characterizing past research relevant to map-based navigation, we offer some general ways in which a developmental approach may be useful in designing map-navigation curricula. We then discuss the ways in which developmental psychology undergirds a particular set of curriculum materials—*Where Are We?*—designed to enhance elementary school children's map-navigation skills (Kastens, 2000). We conclude by discussing the kinds of approaches that are needed to evaluate real-world educational curricula, drawing examples from past and ongoing evaluations of *Where Are We?*

THE ROLE OF MAPS WITHIN AND BEYOND GEOGRAPHY

The Geography Standards Project (1994, hereafter *Standards*) defines geography as ''an integrative discipline that brings together the physical and human dimensions of the world in the study of people, places, and environments. Its subject matter is Earth's surface and the processes that shape it, the relationships between people and environments, and the connections between people and places'' (p. 18). How do people learn about this complex geographic world? One mechanism is via direct, real-world experience as we move within environments; travel from one location to another; and observe phenomena that persist or change over days, months, years, or milennia. Such experiences vary dramatically across cultures, times, and locations. For example, our direct experience of the world differs markedly as a function of whether we live inland or on the sea; whether we reside in hunting, agrarian, or urban societies; whether we travel by foot, bicycle, car, train, or airplane; and whether we live in friendly or hostile communities or in temperate or tropical zones.

Irrespective of one's cultural, geographic, and historical context, however, no one individual can experience very much of Earth directly. Thus, much of our knowledge about Earth must come from representations. The kinds of representations available to an individual also vary dramatically as a function of one's cultural context. Cultures record and communicate information about their near and distant worlds with representations as diverse as stick charts, woodcarvings, photographs, scale models, and paper maps (e.g., see Downs, 1985; Downs & Liben, 1993; Harley & Woodward, 1987; Stea, Blaut, & Stephens, 1996; Tversky, 2001).

Maps have had an especially important role within geography education. The very first *Standard*, for example, states that students should know ''How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective'' (Geography Standards Project, 1994, p. 61). The authors of the *Standards* go on to provide age-graded recommendations about what specific knowledge should be mastered and about what behaviors might be taken as demonstrations of that knowledge. By the end of fourth grade, for example, children should be able to ‘‘interpret aerial photographs or satellite-produced images to locate and identify physical and human features. . . . Examine a variety of maps to identify and describe their basic elements . . . and design a map that displays information selected by the student’’ (p. 106).

While maps are a core of geography education, their importance extends beyond the geography classroom to a diverse range of disciplines, including (among others) ecology, geology, epidemiology, civil engineering, and urban planning. In all these fields, maps are more than simple repositories of location information: they are ‘‘realizations’’ (Downs, 1985). Maps are realizations in the sense of making something real or concrete. They provide a concrete depiction of Earth, making it possible to see portions of Earth that would otherwise be unavailable because they are too large, too distant, or otherwise inaccessible (e.g., the ocean floor). Maps are also realizations in the ‘‘ah-ha’’ sense of discovery. Maps may generate new hypotheses. For example, in the middle 1800s, Snow plotted cholera cases on a street map of London (see Gilbert, 1958). This map revealed that cases clustered around certain water pumps, thereby suggesting the water-borne nature of the disease and implying a simple intervention (removing handles from infected pumps). Maps may also be used to test hypotheses. For example, the examination of same-scale maps of bathymetry and earthquake locations along the Mid-Atlantic Ridge provided a test of the theory of continental drift (Lawrence, 1999; Menard, 1986). Map education helps children appreciate these hypothesis-generating and hypothesis-testing functions of maps and may thereby also enhance their ability to use scientific visualization tools more generally (e.g., see MacEachren, 1995).

Map education may also facilitate an even more basic understanding of the very nature of representation, an understanding that is not automatic. Young children find it difficult to use objects in a ‘‘stand for’’ relation to other objects (DeLoache, 1995). Older children continue to be confused about which aspects of a symbol carry meaning about the referent and which are simply incidental qualities of the representation itself (Liben, 1999, 2001). Illustrative are reports of preschoolers interpreting a red line on a road map as meaning that the referent road is itself red, and second graders laughing at the idea of using asterisks to represent file cabinets because file cabinets do not look like stars (Liben & Downs, 1994). A curriculum that teaches children about the flexible assignment of symbols on maps may well enhance understanding of representations more generally (Liben, 1999).

Experience in producing and using maps may also facilitate spatial skills (e.g., see Liben, 2000, 2001; Liben & Downs, 2001; Uttal, 2000). For example, perhaps learning to ‘‘see’’ height in flat contour lines facilitates one’s ability to visualize a building from an architectural blueprint. Or perhaps learning to visualize environments from different vantage points facilitates one's ability to mentally rotate images of engine pieces and thus their assembly. Spatial knowledge is real-world knowledge too (e.g., Gattis, 2001; Gauvain, 1993a, 1993b). Providing opportunities to develop spatial skills within the school curriculum is also important from the perspective of educational equity. That is, education that is directed toward spatial skills might help to overcome the persistent finding that, as a group, girls and women tend to perform at lower levels on spatial tasks than do boys and men (e.g., Halpern, 2000; Liben, 1991; Linn & Petersen, 1985; Ruble & Martin, 1998).

And finally, but most importantly for the current focus on ''real-world knowledge,'' map education is important quite simply because maps *themselves* are important for our daily lives. We have maps in our glove compartments; we obtain them from tourist centers; and we see them in shopping malls, on hospital walls, and on the back of our hotel room doors. We rely on them to plan our vacations, to explore new cities, to find our way to the right street or room for job interviews, to find a store, to locate a book in the library, and to escape from burning buildings. Thus, even apart from the lessons that maps may teach children about the global community, apart from their use in a diverse range of professions, and apart from the contribution they may make to children's general symbolic and spatial reasoning, maps have a strong, real-world utility for the person on the street. As explained next, in this article we focus primarily on one particular map function—maps as navigational tools.

MAPS AS NAVIGATIONAL TOOLS

Map Functions

Geographers attend to multiple map functions. An introductory cartography text, for example, notes that maps ''record and store information; serve as computational aids; serve as aids to mobility; summarize complex, voluminous data; help us to explore data (analyze, forecast, spot trends); help us to visualize what would otherwise be closed to us; serve as trigger devices to stimulate thought'' (Muehrcke, 1986, p. 14). The layperson is likely to focus on maps' navigational function. When asked to explain what maps are, preschoolers most commonly give responses such as ''Something if you get lost, it helps you to get somewhere . . . maybe home'' (Liben & Downs, 1986; Liben & Yekel, 1996). Older children and adults are also more likely to mention wayfinding than other uses when asked to define or explain maps (Gerber, 1981, 1984; Griffin, 1995).

Our own focus is likewise on maps as navigational tools. Although we have argued often for expanding students' appreciation for the variety of maps and map functions (see especially Liben, 2000, 2001; Liben & Downs, 1989, 1994), we have selected this more restricted focus here for several reasons. First, and as justified above, using maps for navigation is an important real-life activity and thus fits the focus of the current issue of *Develop-*

mental Review. Second, many of the skills needed to use maps for navigation (e.g., interpreting symbols and understanding scale) are also needed to use maps for other purposes. Third, the navigational use of maps involves direct action and is thus consistent with our belief that self-regulated, direct action in the physical world is an essential beginning point for cognitive development and thus for education (e.g., Dewey, 1916; Piaget, 1964). Finally—and perhaps best understood as an overarching reason that subsumes the prior three—the navigational use of maps necessarily links the representation to a specific reality. Although one might naively suppose that the link between symbolic space and real space would be at the very heart of map research and map teaching, in actuality it is not. That is, as discussed below, much of the research in the scholarly community and many of the curricula developed for the classroom focus not on the links between symbolic space and referent space, but rather on links between two different symbolic representations (e.g., between prose and graphic descriptions). By teaching map-based navigation, one necessarily addresses the relation between the representation and the real world.

Interestingly, despite the many reasons one might be interested in studying and teaching the navigational use of maps, there has been surprisingly little research addressed to basic or applied questions concerning map navigation. In the following sections we provide a brief review of the extant work and offer some suggestions about what factors may have helped to shape the scholarly landscape.

Map-Based Navigation: The Basic-Research Terrain

There is a large and growing literature on human wayfinding (see, for example, Golledge, 1999a). Much of this research has examined individuals' abilities to reason about or make their way around environments based on cognitive maps (Downs & Stea, 1977). Some investigators have studied the impact of individuals' preexisting cognitive maps (established from prior direct experience in environments or from prior exposure to maps) on behaviors such as planning or executing routes or judging distances or directions from one location to another (e.g., Acredolo & Boulter, 1984; Anooshian & Young, 1981; Cohen, Baldwin, & Sherman, 1978; Montello, Lovelace, Golledge, & Self, 1999; Stephens & Coupe, 1978). Other investigators have studied the impact of cognitive maps that are established during the experiment itself, perhaps by giving participants direct experience in moving around the space or by exposing participants to representations of the space via slides, videos, or maps (e.g., Allen, Kirasic, Siegel, & Herman, 1979; Allen & Ondracek, 1995; Cornell & Hay, 1984; Dabbs, Chang, Strong, & Milun, 1998; Darvizeh & Spencer, 1984; Galea & Kimura, 1992; Hirtle & Hudson, 1991; Kaplan, 1993; Kosslyn, Pick, & Fariello, 1974; Montello et al., 1999; Uttal & Wellman, 1989; Weatherford & Cohen, 1980). Work in this tradition asks participants to answer questions by drawing upon *cognitive* representations (including memories of just-seen maps), but not upon ‘‘real,’’ concurrently available physical representations (i.e., spatial products; see Liben, 1981a).

A smaller group of investigations has concerned individuals’ abilities to perform various tasks with concurrent access to maps. However, most of this work uses materials or procedures that are not highly representative of real-world map-based navigation. In some cases, the space being mapped is highly artificial as in a layout of disks glued to a floor and a map showing paths from dot to dot (e.g., Aubrey & Dobbs, 1990). In some cases, the spaces are so small and simple that one would not normally use a map for navigation within the space, as when navigation involves a single laboratory room, toy terrain, small playground, or field. Even when slightly larger environments such as a series of corridors are used and even when portions of the navigational space are hidden from view by a screen, cardboard divider, maze structure, or wall, the terrain itself may be quite small and simple (e.g., Blades & Spencer, 1987a, 1987b, 1989; Bluestein & Acredolo, 1979; Bremner & Andreasen, 1998; Freundschuh, 1990; Presson, 1982; Sandberg & Huttenlocher, 2001; Scholnick, Fein, & Campbell, 1990). As a corollary, the maps of these experimental spaces are likewise simple, containing a small number and limited variety of symbols. From the perspective of evaluating theoretical questions about whether or not children of a particular age do or do not have the *competence* for map use, such research is extremely valuable. However, from the perspective of discovering (and ultimately educating for) the use of real maps in the real world, it is insufficient. We would argue that it is also critical to study the processes involved when people are faced with more complex, ecologically valid environments, maps, and map tasks.

There are some studies that do allow respondents to make concurrent use of ecologically valid maps while performing a required task. For example, participants may be asked to select or to indicate a route on a campus or road map to indicate an appropriate route to get from one location to another or to explain a route to someone else who cannot see the map (e.g., Bailenson, Shum, & Uttal, 1998; Blades & Medlicott, 1992; Brewster & Blades, 1989; Gilmartin & Patton, 1984). Some investigations have employed complex and ecologically valid maps, as in research in which college students were asked to plan routes using transit system bus maps (Bartram, 1980; Garland, Haynes, & Grubb, 1979). However, neither of these studies tested whether respondents could actually implement the indicated routes in the real world.

We have been able to find very few studies that have addressed participants’ use of real maps in navigating real spaces. Even these are not always fully informative because map-users’ navigational success is sometimes monitored by the map users themselves. Thus, for example, Talbot, Kaplan, Kuo, and Kaplan (1993) studied visitors’ use of alternative versions of hand-out maps for wayfinding in a museum, and Yarnal and Coulson (1982) studied hikers' reactions to alternative trail maps in a recreational area. In both studies, dependent measures were primarily users' own reports about map preferences and wayfinding successes and failures. Bronzaft, Dobrow, and O'Hanlon (1976) asked adults who had lived in New York City for less than 7 months to use the subway system maps to get from one designated location to another and to keep logs of their ongoing actions. Logs revealed many incorrect or inefficient decisions, including some that could be traced to users' failures to consult map legends and others to their misunderstandings of the way that transfer points were symbolized. In a rare study in which investigators observed map users' actions directly, Gerber and Kwan (1994) found that of the preadolescents they asked to use a street map to navigate (by foot) through a town, fully one-quarter were completely incompetent map users. Although the relevant literature is thus limited, taken together the empirical literature is suggestive that even as late as adolescence and adulthood, map-based navigation remains a challenging task.

Map-Based Navigation: The Intervention-Research Terrain

The domain of geography education has also addressed children's map skills, but again relatively little of it has focused on relating information in the maps to a directly experienced space. First, despite the fact that the authors of the *Standards* place maps centrally in educational goals and activities (see discussion above), they never explicitly address education for individuals' use of maps for navigation. Second, the research literature places most of its emphasis on other issues. For example, investigators have studied children's ability to use maps to identify places, to find the relation between two places, or to perform component skills needed for these purposes (e.g., Dale, 1971; Gerber, 1981, 1984; Goldberg & Kirman, 1990; Hawkins, 1977; Howe, 1933; McAuley, 1962; Schneider, 1976; Towler & Nelson, 1968). Considerable work in geography education has also focused on how students learn information that is depicted on maps or presented in a text accompanying them (e.g., Gilmartin & Patton, 1984; Postigo & Pozo, 1998; Rittschof, Griffin, & Custer, 1998; Rittschof & Kulhavy, 1998; Rittschof, Stock, Kulhavy, Verdi, & Doran, 1994; Scevak, Moore, & Kirby, 1993; Winn & Sutherland, 1989). Using the terminology developed elsewhere (see Liben, 1997), these tasks largely test the participant's understanding of ''representational correspondences'' (that is, relations between two representations such as between two maps or between map and text) or their skills in ''meta-representation'' (that is, an ability to reflect upon or explain the relation between map and place). They do not, however, challenge ''production'' or ''comprehension'' skills which require, respectively, the direct linking of information from the map to a real space or the reverse.

Although limited, there is some research literature relevant to teaching map navigation to children. Some of this work has tested programs designed to teach elements necessary for map use, including scale, directions, and symbols (e.g., Atkins, 1981; Savage & Bacon, 1969). However, assessment of the learned skills has generally been accomplished by using tasks in which children must interpret or draw a map rather than demonstrate their understanding in a real space. In one of the few educational studies examining the effect of different teaching methods on children's navigation in a real space, Griffin (1995) compared effects of navigation instruction given in the natural context (''situated cognition'') to instruction given in the classroom. Students in the situated cognition group did better on a navigation task in a very similar environment. However, their advantage did not generalize to a written assessment or to a navigation task using a different kind of environment. In addition, Griffin and Griffin (1996) later found that students who received situated instruction performed no better than those given conventional instruction on a subsequent navigation task and actually performed *worse* on a delayed navigation task. In summary, there is also relatively little research addressed to educational interventions for map navigation.

Accounting for the Lacuna in Map-Navigation Research

It is potentially puzzling to juxtapose the two arguments made above. First, we argued that the best known role of maps is as a tool for navigation. Yet, second, we argued that researchers and educators have paid relatively little attention to maps as navigational tools. What might account for this paradox?

One explanation is that scholars of human behavior generally tend to focus on mental phenomena. In the arena of navigation, this means that researchers and practitioners are most interested in the role of *cognitive* maps (Downs & Stea, 1977). Although cognitive maps are not necessarily ''accurate renderings of the real world,'' and thus do not necessarily allow ''a traveler . . . to make accurate judgments about the location, distribution, pattern, connectivity, or other spatial relations of features'' of the environment (Golledge, 1999b, p. 45), they nevertheless routinely allow travelers to get successfully from one place to another.

Another explanation may rest in the fact that among those researchers and practitioners who are interested in the use of ''real'' maps for wayfinding, many think that map understanding is an early and easy accomplishment. If this is the case, map-based navigation would be relatively uninteresting to study or teach. For example, Blaut, McCleary, and Blaut (1970) suggested that even very young preschoolers can understand iconic place representations (aerial photographs) by employing perceptual skills mastered in infancy and further that young children can readily plan appropriate routes on representations (see Liben & Downs, 1989). If map use is early and automatic, educators need not concern themselves with fostering basic skills, but may instead design programs that take these essential foundations as given.

Within the field of educational research, there is probably also a pragmatic explanation for the relative inattention to education in map navigation, namely that much of the classroom use of maps takes place not in the context of the school subject of geography but rather under the more general umbrella of ‘‘social studies.’’ Under these circumstances, maps are used as the means for conveying information about topics such as history (e.g., exploration routes) or civics (e.g., boundaries of congressional districts) rather than as an educational focus in their own right. Outcome measures thus typically concern mastery of the history or civics content rather than skill in understanding and using maps.

Map-Based Navigation: The Need for Education

There is ample reason to reject both the view that map-based navigation is unnecessary and the view that map-based navigation is necessary but easy. First, despite the fact that cognitive maps may often be adequate for wayfinding, many people do get lost, particularly when they must travel to unfamiliar places. At the anecdotal level, many of us have experienced or have heard others tell of being hopelessly lost or of unintentionally following the ‘‘scenic route’’ to a destination. Newspapers often publish feature articles on sense of direction or, more commonly, on its absence. Government agencies plan and implement rescue programs in part developed by analyzing earlier instances of lost hikers, hunters, and bikers (e.g., Cornell, Heth, Kneubuhler, & Sehgal, 1996; Heth & Cornell, 1998).

Being equipped with a map does not necessarily allow individuals to interpret the symbolized space correctly. Among the most dramatic illustrations are those in which a misguided map user causes property damage or suffers serious bodily harm. For example, a *Los Angeles Times* article entitled ‘‘Pair Awarded $51,000 for Trees Felled in Error’’ reported a settlement to a couple who had lost timber and suffered other property damage from a logger’s error. In his explanation to the court, the logger wrote: ‘‘The way the map was shown to me didn’t help, as it should have been turned the other way’’ (‘‘Pair Awarded,’’ 1989). Military personnel have created international incidents or come to harm from map-reading errors. For example, ‘‘A British army spokesman claimed yesterday that soldiers who crossed from Northern Ireland into Co Monaghan as a result of a map-reading error on Monday evening were attacked by a group of people and one soldier was slightly injured’’ (British Soldiers, 1999). Although it is possible that ‘‘map-reading errors’’ are excuses for intended actions by military personnel, they are unquestionably true errors among civilians. Particularly horrific are reports of tourists murdered for having gone astray. For example, a Dutch tourist vacationing in Florida was fatally shot when ‘‘she and her husband got lost and stopped to ask for directions in a poor, crime-ridden Miami neighborhood . . . As her husband got out of their rental car with a map in hand, [one of the men] fired a shot through the [passenger] car window’’ (Skipp & Faiola, 1996).

Less dramatic but perhaps equally convincing are results of scholarly research. Investigations using *You Are Here* maps, for example, have shown that people often head off in the wrong direction after consulting the map. This is particularly true when—as is often the case in the real world of airports, malls, and campuses—the maps are posted out of alignment with the depicted environment (e.g., Levine, Marchon, & Hanley, 1984). Findings from our own recent research (Liben & Stevenson, in preparation) are consistent with the conclusion that real-world map use is difficult, even for adults. We took college students during their first semester on campus to various locations, handed them the relevant section of the campus map (modified only slightly from the map normally provided to campus visitors), and asked them to place an arrow sticker on the map to show where they were standing and which direction they were facing. Many students found the task difficult and made dramatic errors. To illustrate, Fig. 1 provides a composite of the

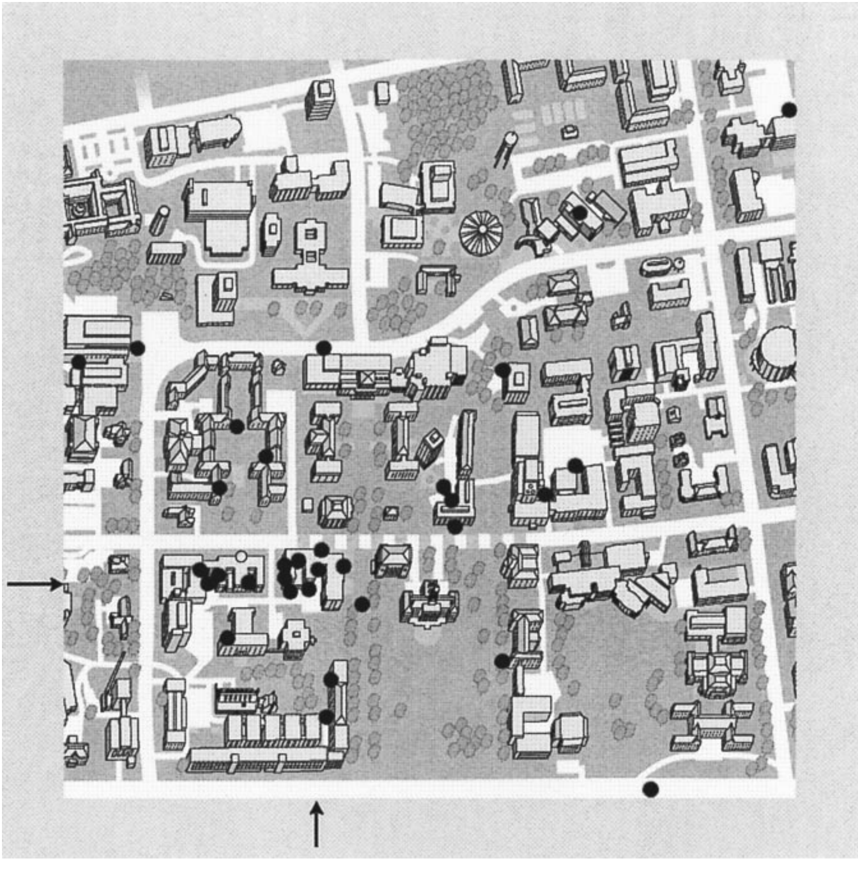


FIG. 1. A composite map showing locations of college students' responses when asked to place an arrow on a campus map to show where they were. (Correct location is indicated by intersection of arrows shown on the left and bottom borders.)

locations of all arrow placements for a single item. The location errors are particularly striking given that although students were relatively new to the environment, they had at least some familiarity with the campus and given that they may also have already acquired some familiarity with the map (which is posted throughout the campus).

In summary, despite scholarly pronouncements about the ease with which individuals are able to understand the relation between depicted and real locations and to use maps to find their way, the empirical data demonstrate that at the very least, significant portions of the population do not find such tasks to be simple. These findings support the need to design and implement a developmentally motivated curriculum for enhancing map-based navigation. In the remaining sections of this article we discuss the cognitive-developmental underpinnings of map navigation, describe one suite of curriculum materials designed to teach map navigation, and provide a structure for approaching curriculum evaluation.

COGNITIVE-DEVELOPMENTAL UNDERPINNINGS OF THE NAVIGATIONAL USE OF MAPS

Understanding Maps

From the perspective of developmental psychology, what does it take to understand maps? Understanding two kinds of links between space and map is essential: *representational* and *geometric correspondences* (Liben & Downs, 1989, 1991). The former refers to understanding that particular components of the representation are used to stand for particular things or concepts of the referential space. As noted above, children only gradually learn which features of the symbol carry representational meaning and which do not (see Liben, 1999, 2001).

Geometric correspondences concern the spatial relations between the representation and the referent space. From a cartographer's perspective (see Downs, 1981), there are three major kinds of geometric decisions in creating a given map: the *scale* relation between the size of the features as represented on the map and the size of the corresponding features of the referent space (e.g., a 1:10,000 scale); the *viewing azimuth,* or direction from which the referent space is depicted (e.g., whether a land mass is depicted with north or west at the top); and the *viewing angle,* or the degree of tilt from which the space is depicted (e.g., whether the landscape is shown from an orthogonal angle of 90° or an oblique angle such as 30° or 45°). The extent to which these cartographic qualities are processed by a map user may depend on the spatial concepts of the user, the requirements of the task, and the kind of space being depicted (Liben, 2001).

Spatial Concepts in Map Understanding and Use

As discussed elsewhere (Liben, 2001, in press), there are gradual and generally predictable developmental achievements that provide the cognitive foundations for understanding map scale, viewing azimuth, and viewing angle. The developmental progressions in spatial concepts described by Piaget and Inhelder (1956) provide a particularly useful approach (although not the only possible approach; see Newcombe & Huttenlocher, 2000, for alternatives). They proposed that children gradually construct—through active interactions with their physical world—increasingly flexible geometric systems with which to represent space. Preschool children are said to conceptualize space in topological terms (e.g., notions such as ‘‘next to,’’ ‘‘on,’’ and ‘‘near’’). Children in early and middle childhood construct projective and Euclidean concepts. Projective concepts involve the view-specific nature of the spatial representation or experience and are thus important for figuring out how some scene would look from different directions and how some object would appear from different vantage points (e.g., understanding that the top of a cup would look circular from overhead but elliptical from an oblique angle). Euclidean (or metric) concepts provide stable, abstract, overarching systems with which to represent space (e.g., a horizontal and vertical grid with a specified point of origin). These concepts provide the foundation for measurement and conservation of distance and angle.

It is easy to link these three conceptual systems to map understanding. For example, working within the internal map space itself (i.e., apart from a map’s connection to the depicted environment), one might use topological concepts to determine if the bus stop shown on the map is next to the movie theater or the public library; projective concepts to interpret maps of differing orientations (e.g., Europe seen from the south versus the east; see Fig. 2) or of differing projections (see Fig. 3); and metric concepts to figure out the shorter of two routes between home and hospital. Projective and metric issues are not entirely independent. A striking illustration comes from the criticism levied at former President Gerald Ford for taking a ‘‘detour’’ at the taxpayer’s expense to make a campaign speech. However, as shown in Fig. 4, this criticism rests on failing to understand the meaning of a route plotted on a Mercator projection. If it is instead shown on an orthographic projection, it is evident that he took the shortest path (Muehrcke & Muehrcke, 1998).

An extensive research literature (reviewed in Liben, 2001, in press) has shown age-linked (although not necessarily universal) improvements in performance on tests of the spatial concepts identified by Piaget and Inhelder. There has been less work on the finer grained question of whether basic projective and Euclidean concepts are linked to performance on mapping tasks in individual children. Significant, but modest, links have been reported (Liben & Downs, 1993), but most studies linking either children’s or adults’ spatial skills to mapping are concerned with cognitive, not ‘‘real,’’ maps (e.g., Allen, 1999; Allen & Ondracek, 1995; Cousins, Siegel, & Maxwell, 1983; Fenner, Heathcote, & Jerrams-Smith, 2000; Lorenz & Neisser, 1986; Moore, 1975; Pearson & Ialongo, 1986).

As we move beyond the boundaries of the map and consider the map

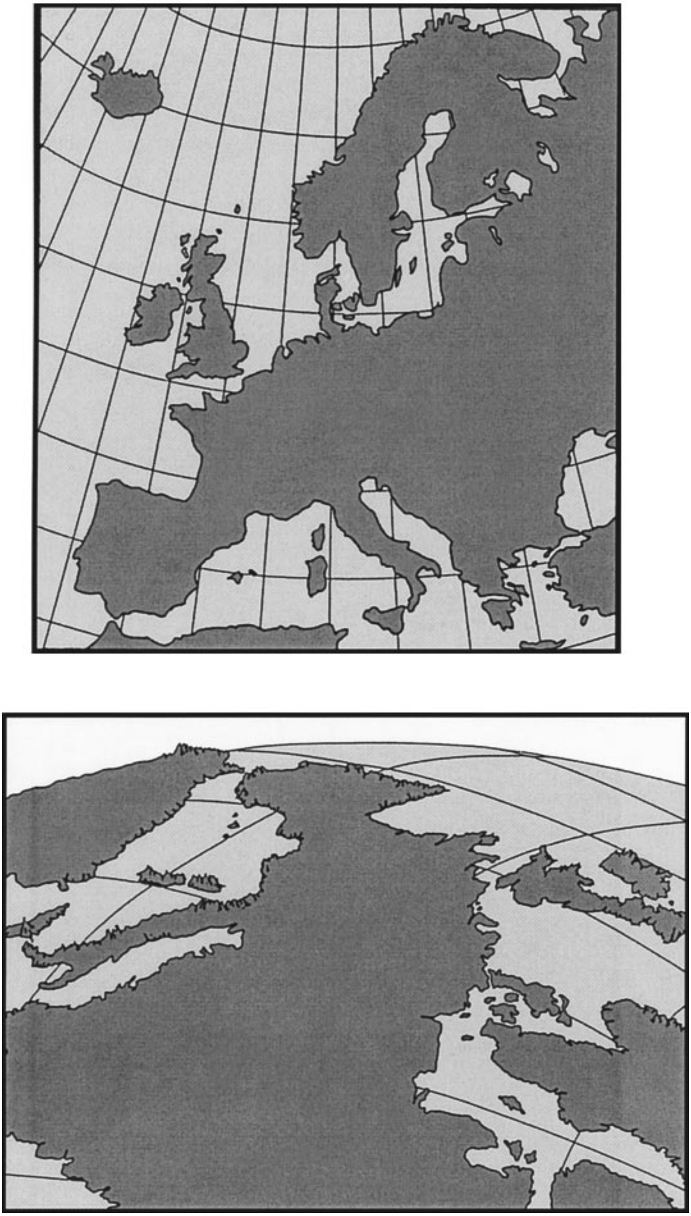


FIG. 2. Two views of Europe. (Top) A traditional view with north at the top; (bottom) a perspective view showing Europe from the east. (Based on Harrison, 1944; reproduced from Liben, 2001.)

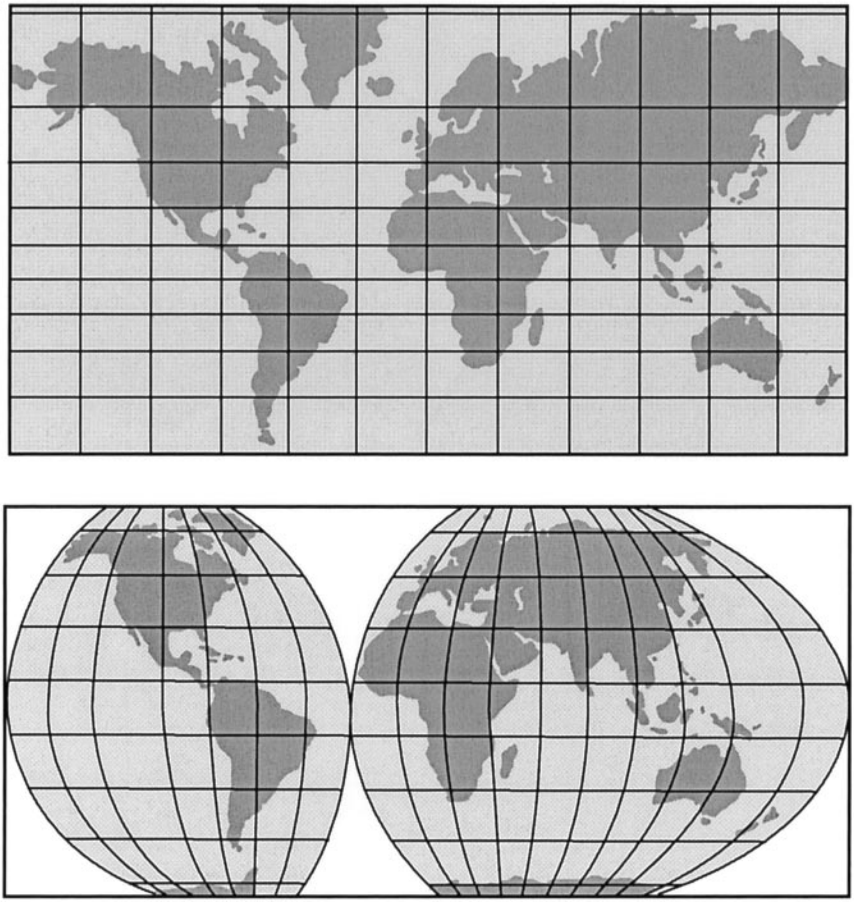
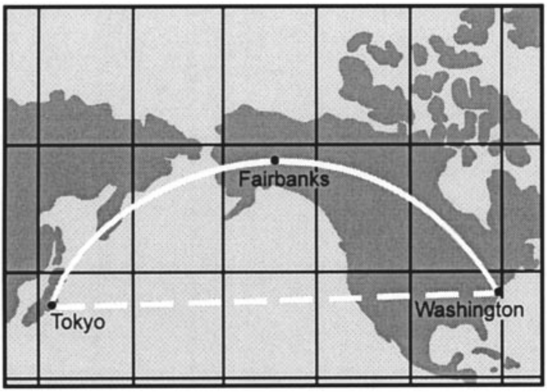


FIG. 3. Sample map projections. (Top) A common Mercator projection; (bottom) an interrupted flat polar quartic equal-area projection. Note, for example, the size of Greenland in each. (Reproduced from Liben, 2001.)

user's understanding of space-to-map or map-to-space relations, the spatial concepts discussed above appear to be, if anything, even more relevant. Topological concepts may be used to identify analogous locations in the space and on the map. For example, if I know I am standing next to a picnic table in the real environment, I can locate my position on the map by finding the depiction of that table. Note, however, that topological concepts alone are effective under only some circumstances (Liben & Yekel, 1996). First, the user must be able to interpret the representational meaning of the map symbol. Children are likely to find this easier when the symbol is motivated by color (e.g., the only brown table and the only brown symbol) or by semantic meaning (e.g., a picture of food) than when the symbol is motivated spatially



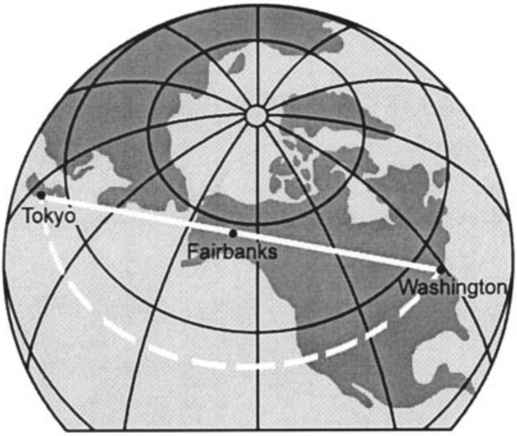


FIG. 4. Map showing route taken from Washington DC to Tokyo by President Ford on a Mercator projection and orthographic projection. (Adapted from Muehrcke & Muehrcke, 1998; reproduced from Liben, 2001.)

(e.g., a nadir view of the table). It is also easier when the symbol is unique. If it is not (e.g., if there are several brown rectangles on the map), the user must disambiguate among symbols, perhaps by drawing on topological concepts (e.g., ''the table between the swing set and the grill''), projective concepts (e.g., first determining the relation between self and space and then reasoning ''the table on my right is the table on the left of the map''), or Euclidean concepts (e.g., ''the largest of the tables'' or ''the table that is about six feet from the swings in the park is the table about three inches from the swings on the map'').

Projective concepts become especially critical when one can approach the target space from many different directions because projective concepts support the coordination of alternative vantage points of the same space. That is, projective concepts allow the user to deal with the alignment problem created when the map depicts the space from one direction and the user approaches the space from another. Multiple entry points are almost always possible in the natural environment, albeit if not in most laboratory spaces (see Sholl, 1995).

Findings from studies using relatively simple maps of small spaces suggest that even preschool children can draw upon topological concepts and use landmarks to solve production and comprehension tasks under some circumstances. For example, preschoolers typically perform quite well in using a map to find objects in a room when the symbols are unique and when the map and space are aligned (e.g., Bluestein & Acredolo, 1979; Presson, 1982). However, preschoolers typically perform quite poorly when the map and space are unaligned, when the map includes multiple symbols of the same kind, or when the map uses symbols that are spatially motivated rather than semantically motivated (e.g., Blades & Spencer, 1994; Bluestein & Acredolo, 1979; Liben & Yekel, 1996). Over the course of the elementary school years, performance on such tasks improves strikingly (Liben & Downs, 1993). These patterns are consistent with the notion that under some conditions, later developing projective and Euclidean concepts are needed to calculate self–map–space links.

There are also data on map use consistent with the notion that metric understanding is a relatively late achievement. For example, preschool children tend to perform particularly poorly when asked to show, on a map, locations on areas (such as the floor) that lack topological or landmark cues (Liben & Yekel, 1996). Similarly, when asked to learn objects' location on a map and then place the objects in the actual room, 4- to 6-year-old children show competence in reproducing configural (topological) relations among objects, but are typically inaccurate in adjusting (metric) scale correctly (Uttal, 1996).

Taken together, these data support the position that topological concepts are generally well established and can be called upon for map navigation even during the preschool years. However, because projective and metric concepts are mastered somewhat later, under some circumstances children will have difficulty on various map-navigation tasks. A map user who does not have well-developed or easily activated (see Overton & Newman, 1982) projective concepts will find it difficult to navigate under unaligned conditions or with maps that rely on projectively derived symbols. A map user who does not have well-developed or easily activated metric concepts will likely find it difficult to locate target locations if the environment and map do not already provide nearby topological cues (landmarks) and will find it difficult to make judgments about scaled distance (e.g., relating how far one has traveled in real space to how far one has traveled in map space).

We would argue that familiarity with the kinds of developmental progressions just reviewed is an essential beginning point for curriculum design. This is not to deny that teachers may well discover some features of children's thinking inductively and make adjustments appropriately. For example, even without knowing Piagetian research on children's projective concepts, a kindergarten or first-grade teacher is likely to discover that children are confused by the relation between right and left on their own bodies and on the bodies of others facing them. These teachers may well be successful in designing classroom activities to help overcome such confusions. However, we believe that it is far more efficient to draw upon the theory and research provided by developmental psychology to create structured, integrated, hierarchical educational programs. Such programs should reduce children's misunderstandings and increase their acquisition of flexible, adaptable, and broadly applicable skills (Liben & Downs, 1994, 2001). At the same time that we explain what we believe is important about a developmentally informed curriculum, it is probably important to add what we do *not* mean, given that there have been misinterpretations in past literature (see Blaut, 1997a, 1997b). We do *not* mean to imply that map education should simply be postponed until underlying cognitive development is further along (see also Downs & Liben, 1997; Liben & Downs, 1997).

Having reviewed some fundamental concepts on which map-navigation education should rest and having provided a brief discussion of how developmental theory and research may inform educational practice at the general level, we now turn to a discussion of the links between developmental work and specific instructional materials designed to teach map navigation to elementary school children.

TEACHING MAP NAVIGATION: DEVELOPMENTALLY INFORMED PRACTICE

Motivating and Characterizing Map-Navigation Curricula

Although map navigation is just the kind of real-world skill discussed in the introduction that is probably best acquired in the course of everyday life, our current culture makes this path of acquisition difficult. Suburban children are likely to be passive passengers in school buses and endless car pools and thus to have little control over their own routes to and from schools, friends' homes, or activities. Urban children are likely to be faced with issues of personal safety and thus have restricted opportunities for independent, map-based travel. Even children who are privileged enough to use maps during car, plane, or hiking trips are likely to encounter such experiences only rarely. As a result, instruction in map navigation must be undertaken by the formal educational system.

However, it is likewise difficult to provide *in situ* learning experiences within the school context. Field trips (e.g., bus trips to environmental centers) are expensive and logistically demanding, and trips within the school neighborhood are often impractical (e.g., because of exposure to traffic dangers in many suburban locations, exposure to social dangers such as crime or drugs in many cities, or insufficiently differentiated school neighborhoods in some rural locations). Even in settings in which trips near the school are practical, teachers may find it too difficult to obtain or make maps of the local area.

Extant educational curricula have typically responded to these constraints in one of two ways. One approach has been to draw upon the immediate environment of the classroom (or perhaps the school grounds) for initial map lessons. Thus, for example, mapping curricula often begin by having children draw or work with maps of their classrooms, using these maps as an occasion to discuss basic map qualities such as scales and symbols. Given the inherent limitations of these spaces (which include being small in size, entirely visible at once, highly familiar, and neatly bounded), they provide only restricted opportunities to develop children's understanding of space–map links and to challenge children's navigation skills.

A second approach has been to offer more interesting and complex referent spaces by using distant or imaginary places as the referent space to be mapped or negotiated. Illustrative are the two sets of classroom materials referenced under the index term ''navigation'' in the National Academy Press's *Resources for Teaching Elementary School Science* [National Academy of Sciences (NAS), 1996]. Both of these employ the Bank Street (1985) *Voyage of the Mimi* videotape series, which describes a voyage to the Gulf of Maine to study humpback whales. One lesson includes ''computer navigation activities'' in the course of learning about various topics such as electricity, sound, and ecology; the other focuses more specifically on navigation to develop ''the concepts, skills, and tools that help navigators find their way at sea'' (NAS, 1996, p. 108). However, both deal with distant oceans and a form of travel that is likely to be unfamiliar and irrelevant to most students.

Other elementary school map-skills materials make heavy use of imaginary ''referent'' spaces, perhaps describing features of an imaginary town or island and asking children to create a map of that space or follow directions through it. Our ongoing work (Goodwin, Kastens, Liben, & Stevenson, unpublished data), using a classification scheme developed earlier (Liben, 1997), reveals that classroom materials have a paucity of production tasks (in which the student creates or modifies a map to show information about the referent space) and comprehension tasks (in which the student performs an action in the referent space in response to information from the map). Instead, materials emphasize representational correspondence tasks (in which the student compares two different spatial representations, typically without looking at the real space) and meta-representational tasks (in which the student articulates his or her theoretical understanding of the relationship between map and place). Although these latter two categories of mastery are necessary, we believe that they are incomplete. Students must also learn to connect what they see around them to what is on a map.

It was a perceived need for sustained school-based education on space-to-map and map-to-space skills that led to the development of the suite of curriculum materials entitled *Where Are We?* (*WAW?;* Kastens, 2000). The major conceptual premise of this curriculum is that the ability to understand maps of distant places and of movement within them (e.g., traversing oceans by ship and planets by spacecraft) or to interpret the spatial distribution of data on a thematic map (e.g., distributions of pollutants) rests on the more basic ability to understand maps of everyday environments encountered by everyday means (e.g., exploring a park by foot). The major pragmatic premise of the curriculum is that it is logistically difficult for schools to teach map navigation in the real-world environment. The *WAW?* curriculum was designed to accommodate to these conceptual and practical constraints by including mapping activities that not only use the child's immediately available environment (the desktop and classroom), but that also extend the map-to-space and space-to-map links by simulations. Thus, the computer software that forms the core of the *WAW?* curriculum simulates ''everyday'' movement and map-navigation experiences in an unfamiliar, complex environment. Although computer simulations of movement through spaces are, of course, still representational, they are at least more similar to the experiences one has in moving through a real environment than are linguistic descriptions of distant or imaginary places.

The *WAW?* curriculum is described in more detail below. However, before turning to discussions of *WAW?* and of issues related to evaluation, it is important to acknowledge explicitly that we are not disinterested parties in selecting this curriculum example. One of us (Kastens) developed *WAW?*, another of us (Liben) served as a member of the advisory board during material development, and all three of us are now working on a collaborative project designed to evaluate the effectiveness of *WAW?* (see unnumbered footnote on title page). Although our personal roles in this project place us in the best position to describe the materials and to initiate the evaluation process, they do not place us in the best position to act as disinterested judges. Our hope is that the work described here will encourage other researchers and classroom teachers to replicate and extend these evaluations and that the outcomes of such work will, in turn, inform future modifications of the curriculum.

An Overview of the Where Are We? Curriculum

WAW? includes a set of 12 classroom lessons summarized in Table 1. The software for these lessons runs on both Windows and Macintosh computers, in Spanish or English, with verbal instructions given in both written and spoken forms. As illustrated in Fig. 5, the left side of the computer screen

TABLE 1
Summaries of *Where Are We?* Lessons[a]

1. Exploring Maps. Students examine a variety of paper maps and discuss the uses of maps.
2. Bird's-Eye View Mapping. Students draw a simple map of the objects on their desks.
3. Map Symbols. Students use the key on the *Where Are We?* poster map to identify objects on the map, and to imagine what is seen by someone standing at a particular location.
4. Introducing the Software. Students learn how the software works by using ''Exploring the Park'' mode.
5. Landmarks. The lesson introduces the value of landmarks in map reading and navigation, through guided use of ''Are We There Yet?'' mode.
6. Keeping Track of Where You've Been. Students keep track of their route in ''Are We There Yet?'' mode and practice returning to their starting point.
7. Planning a Route. Students plan a route to a destination and anticipate what they should see along that route. Using the ''Exploring the Park'' mode, students test their predictions and verify their plan.
8. Map Scale. By contrasting the distance traveled in the *Where Are We?* video with the distance the dot advances across the map, students see the difference in size (scale) between the map and the represented landscape. They use the map scale to estimate sizes and distances in the *Where Are We?* scene and on other maps.
9. The Compass Rose. Students use a compass rose in the classroom and on the computer map to figure out the direction someone is facing or moving.
10. Putting New Information on the Map. Students find some features that are in the video but missing from the map, figure out where they should be located on the map, and add the appropriate symbols. This lesson models the use of maps by geologists, ecologists, architects, town planners, and many others who use maps as tools for organizing spatial information.
11. Lost! Using map symbols, landmarks, and compass directions, students make observations about the landscape around them in order to infer their location on the map. This lesson simulates the situation where walkers or motorists realize they are lost, pull the map out of a backpack or glove compartment, and use visual clues in the surrounding terrain to figure out where they are on the map.
12. Summing Up. Comparing Maps with the Real World. Students demonstrate their understanding of the similarities and differences between a map and the real world by completing a table.

[a] Reproduced from Kastens (2000).

shows a schematic park map in nadir (plan) view, while the right side displays video films of the eye-level view seen as someone walks through the park at a normal walking pace. By clicking on ''turn left,'' ''turn right,'' or ''move forward'' arrows, the user controls which route is taken through the park.

The software provides four modes. ''Exploring the Park'' introduces users to the software, the videotaped scenes, and the map. A red dot and arrow appear on the map to show the user's position and viewing direction, and these move as the user steers a route through the park via the arrow clicks. ''Are We There Yet?'' simulates the most common real-world map task:

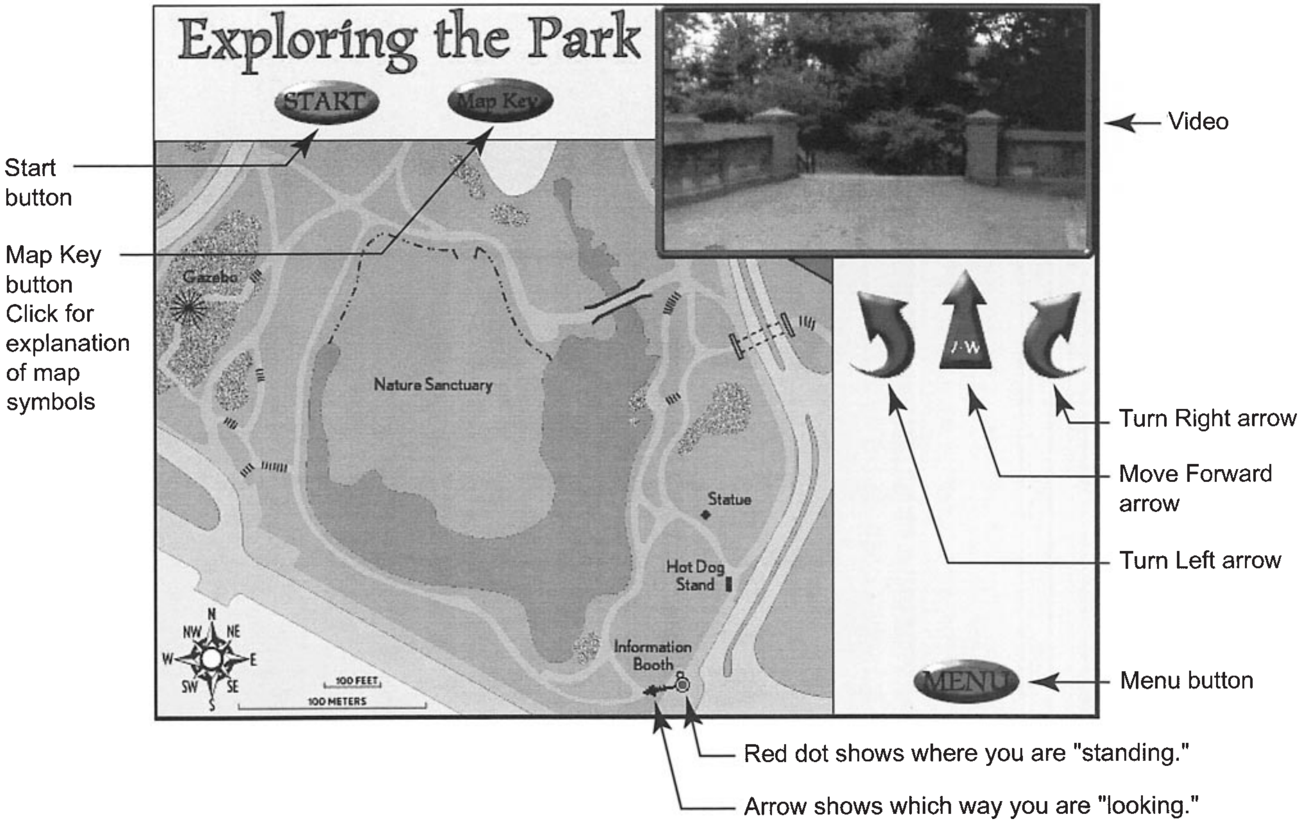


FIG. 5. Annotated screen of *Where Are We?* in the ''Exploring the Park'' mode (Kastens, 2000). (Actual display was in color.)

using a map to find one's way from a known starting point to a desired destination. In ''Lost!,'' users are dropped at an unknown location (not indicated in any way on the map), and they are challenged to figure out where they are by examining the videotape view, looking around, and moving through the videotaped environment if necessary. Users indicate their answer by clicking on the map. Finally, ''Add to the Map'' introduces maps as a tool for organizing information spatially. Students are asked to observe objects such as lampposts as they ''walk'' through the (video) environment and then indicate the locations of these objects by sliding appropriate symbols onto the map.

In addition to the lessons and the software, the teacher's guide (Christie-Blick, Kastens, Barlaz, Kaplan, & Katz, 2000) discusses the links between the *WAW?* curriculum and the *Geography Standards;* offers lessons and ideas for facilitating map-use strategies for classroom, computer lab, and field settings; and provides assessment tools.

Developmental Underpinnings of WAW?

As already implied in prior discussions, fundamental to the *WAW?* curriculum are the premises that development progresses from action to cognition, from concrete to abstract, and from familiar to unfamiliar. These premises are consistent with a long tradition of constructive theories in developmental and educational psychology, including, for example, Baldwin (1906), Bruner (1960, 1966), Dewey (1916), Piaget (1964, 1971), and Werner (1957). The *WAW?* software is aimed at simulating real-world experience, although of course it does so only imperfectly. For example, the video provides visual, but not motor, feedback (e.g., there is no simulation of the walking itself), it offers only restricted visual experience (e.g., it is presented on a small portion of a computer screen rather than as a surrounding visual field), and it allows only limited user control (e.g., arrow clicks affect only which stored video clip is displayed, but not where the eyes move or how far one ''walks''). A better instantiation of a developmental action theory would be provided by a virtual reality (VR), but until VR technology is widely available in schools, this solution is no easier (and indeed is arguably even harder) than providing instruction in the environment itself.

In the context of discussing technology, it is also relevant to address the growing availability of individual global positioning systems (GPS). It may not be too fanciful to imagine that GPS units will soon be strapped to most children's wrists. Will such technology obviate the need for map-navigation instruction? We would argue that developmental theory and research suggest otherwise. Even if place representations become unnecessary as navigational guides, a curriculum like *WAW?*, which teaches fundamental lessons about representation and spatial thinking, would still be important. The situation parallels the continued importance of teaching children numerical skills and quantitative reasoning despite the availability of calculators.

The preceding discussion is aimed at linking developmental theory and *WAW?* at the general level. How does developmental theory inform the instructional materials of any given lesson? Particularly central from developmental psychology are theory and research on children's developing spatial concepts. As reviewed above, aspects of map use that make demands on projective and metric concepts are likely to be particularly challenging, and thus *WAW?* lessons are designed to aid children in developing their understanding of viewing angle, map scale, and viewing azimuth.

To help children understand viewing angle, early activities (''Lesson 2: Bird's-Eye View Mapping'') provide instruction about creating and interpreting representations of objects from overhead. In keeping with the emphasis on physical, experienced objects, initial activities include creating overhead views of visually present and well-known objects—those on the child's own desk. Similarly, this early lesson begins to address scale, again beginning with the comparison of two specific and kinesthetically experienced spaces—the child's desktop and the scaled map which represents it. However, what extends both of these instructional lessons beyond what might be found in other activity books or lesson plans is that *WAW?* includes software to provide experience in translating between the everyday experience of ''seeing'' a ''real'' (simulated) environment (i.e., videotaped insets of a park) and the representational world of the map.

More specifically, to facilitate understanding of map angle, several lessons provide practice translating between the person's-eye view of the park and the overhead, abstract map of the park. For example, one set of activities (''Lesson 3: Map Symbols'') introduces the selection and meaning of map symbols. A paper copy of the *WAW?* map is used to explain the selection of symbols, to teach that symbols may vary across maps and hence to convey the importance of map keys, and to begin to provide students with practice in figuring out what someone at various locations would ''really'' see when in the symbolized position. The teacher's guide (p. 44) suggests asking, for example, ''What would this person see from where she or he is standing? (*Possible answer: In front of her she would see a path. On her right there would be some water, like a lake. On her left would be grass or bushes*.)''

Another set of activities (''Lesson 4: Introducing the Software'') extends activities that link eye-level views and map views via the computer screen. Unlike the poster-based instruction of the prior lesson, the software lesson now provides actual videotaped eye-level views that can thus be related to map position and orientation. These kinds of relations are further developed in the subsequent three lessons (see Table 1).

To develop understanding of map scale (''Lesson 8: Map Scale''), children work in the ''Exploring the Map'' mode, and teachers are guided to help children discover the relation between ''experienced'' distance and representational distance. For example, the teacher's guide (p. 64) suggests that children should be asked to click the forward arrow a few times and to ''notice that the red dot is moving across the map as we 'walk' along in the video. It seems as if we're walking quite a long way in the video, but the red dot hasn't moved very far. We walk and walk, but we only cover a tiny distance on the map. Why?'' The rest of the lesson includes additional discussions of scale, experienced distance, and represented distance; variations of scales across maps; and practice in reading scale information contained on maps.

The issue of viewing azimuth or orientation is perhaps the most difficult of all to teach effectively. A critical component in map navigation is to understand self, map, and space directions and the relations among them (Liben & Downs, 1993). Map users are especially challenged when they must coordinate information across unaligned frames of reference. As discussed above, children and adults alike have difficulty in using maps that are unaligned with the referent space (e.g., see prior discussion of research on misaligned *You Are Here* maps by Levine et al., 1984; or on misaligned room maps used in research by Bluestein & Acredolo, 1979; Liben & Downs, 1993; and Presson, 1982).

Map users are also challenged by incomplete knowledge of or misconceptions about how to determine direction. Although we have no formal documentation, it appears to us that children are given misinformation about direction remarkably often. In a book on maps by Rhodes (1970), for example, children are told that ''North is always at the top of the map'' (p. 46). This message incorrectly teaches children that direction is fixed with respect to paper space. A second example comes from a set of map skill materials (Rushdoony, 1988) in a unit called ''Orienting Ourselves in the Classroom.'' Teachers are told to prepare manila strips with north, south, east, and west printed on them, then to show the four cardinal directions on the blackboard (a large cross with north at the top), and then to ''put manila strips on the walls (one on each wall—north on the wall behind your desk'' (p. 6). While in some classrooms the wall behind the teacher's desk will indeed be the north wall, clearly this cannot always be the case. Similar to the lesson that north is always at the top of the map, this lesson incorrectly implies that north is always at the front of the room.

Not only are the specifics of these lessons incorrect, they miss an opportunity to teach children about the relativity of frames of reference. If the child moves while some external referent (i.e., magnetic north) remains in place, the *relationship* between the two must change. This issue is highlighted by considering a third example from a series of activity books called *Maps and Mapping* (Taylor, 1993). This book provides an excellent presentation of how to determine north in both environmental and representational spaces. Clear text and graphics show how to use a compass to ''find out which direction North is really in'' (p. 18). Likewise children are shown how to find the orientation of the map: ''. . . place a compass on the map and turn the map around until the North arrow on the map points in the same direction as the needle on the compass'' (p. 18). What is absent, however, is any indication (in text or graphics) about how to find where one is ''on the map.'' Even knowing where one wishes to go is of little use if one does not know where one is starting.

In the *WAW?* curriculum, ''Lesson 9: Compass Rose'' is designed to teach children about directions and about relations among self, map, and space. Given the centrality of this lesson and the varied aspects of the instruction, we have reproduced the lesson in its entirety in the Appendix. The lesson includes instruction on finding cardinal directions in the environment (using the direction of sunrise and sunset for referents in addition to magnetic north), interpreting directions shown on the map (the compass rose), and relating the child's own position to directions (e.g., asking students to face east). Importantly, lessons are geared to teaching *relations* among self, map, and space; to understanding the difference between relative directions of left and right and compass directions of north, south, east, and west; and distinguishing between the use of direction terms to indicate regions versus direction. For example, ''When working with a figurine on the poster map, place the figurine in the northern section of the map. Orient the pointer [showing the direction the figure is facing] toward the south. Ask students: In which region of the map is the person? (*North.*) Which direction is she facing? (*South.*)'' (p. 70). Exercises using the *WAW?* software provide practice in coordinating information about the direction one is facing in the ''real'' (video) world (using the compass) with information about the orientation of the map (using the compass rose). Additional details may be found in the Appendix.

In summary, *WAW?* rests on general premises from developmental psychology concerning the role of action as foundational for representational thought. The software offers experiences that—while not perfect replicas of action in the real world—nevertheless provide simulations that help link human actions to abstract representations. The *WAW?* curriculum is also guided by developmental theory and research on symbolic and spatial development. The target age for *WAW?* (second to fourth grades) rests on developmental work, suggesting that this is the transitional developmental period for projective and Euclidean spatial concepts that are central to map use. That there is a need for this curriculum at all (rather than simply waiting until understanding emerges with maturation) rests on research showing that even many adults have difficulty in mastering fundamental projective and Euclidean concepts and in using them to navigate in the real or represented environment.

Of course, it is not enough to provide an analysis that shows that an educational curriculum is theoretically grounded. One must also provide empirical data to show that the curriculum works. We thus close this article by discussing issues related to curriculum evaluation in general and evaluation of *WAW?* in particular.

EDUCATING FOR REAL-WORLD KNOWLEDGE: THE MULTIPLE COMPONENTS OF CURRICULUM EVALUATION

Curriculum Evaluation: General Observations

Formative evaluation is a routine aspect of curriculum development. The specifics of this process may vary widely, ranging from informal observations of how teachers and students seem to be using and profiting from the curriculum to highly structured data collection and analyses. Irrespective of formality, however, virtually all curriculum developers use the results to revise their pilot or mock-up materials iteratively.

Summative evaluation to test the effectiveness of the final curriculum is less universal. Many profit-making companies (e.g., textbook publishers) are willing to support the cost of developing materials, but not the cost of evaluating them. In part this is probably motivated by the fact that material development—but not evaluation—is essential to get a product on the shelf. It may also be motivated by fear of learning that a product is ineffective. Ignorance of an ineffective outcome is (marketing) bliss.

Even well-intentioned, nonprofit agencies and scholars, however, often short-change summative evaluation. Researchers often find that time and effort needed for developing and revising curricula cut into the time and resources available for summative evaluation. Sometimes the limited time frame makes it difficult to locate entirely new samples of students who had not already used materials during curriculum development. But even when new students are available (perhaps because of a new school year), the teachers most likely to be available are those who were involved in curriculum development. Such teachers have more familiarity with, and probably more enthusiasm for, the curriculum than might normally be the case. Furthermore, some of the curriculum modifications stem from their own earlier suggestions. Thus, apart from the usual difficulties that may occur when those involved in evaluation have a vested interest in the materials, the curriculum may be better suited to these teachers' particular teaching styles than might be the case for a new, randomly selected group of teachers.

When a curriculum is meant to teach ''real-world'' knowledge, there is an additional challenge. We know from both psychological and educational research that transfer of learning is typically poor, even when tasks and settings are highly similar (see Bransford, Brown, & Cocking, 1999, for an excellent review). It is realistic to be concerned that classroom measures will not be sensitive to real-world skills and knowledge, and yet, it may be difficult, expensive, or perhaps even impossible to conduct assessments out in the natural ecology.

Taken together, the constraints commonly encountered within the boundaries of developing curricula speak to the importance of pursuing evaluation research as a focus in its own right. This view is reflected in the recent decision by the National Science Foundation (NSF) to establish a grant program targeted explicitly for research on educational materials developed with prior NSF funding. We are embarking on just such a research grant to study the efficacy of the *WAW?* curriculum. Given that this project is only beginning, we have no findings to report here. Instead, the remainder of this article is focused on two related topics. First, we review briefly the formative and summative evaluations that took place within the context of developing the *WAW?* curriculum itself. Second, we outline the components of the assessment enterprise that we believe are needed to evaluate any developmentally-motivated curriculum intended to teach real-world knowledge. We illustrate each by discussing our emerging *WAW?* evaluation research.

Formative and Summative Evaluation of WAW?

The *WAW?* curriculum was developed in a context of formative evaluation that involved children in six classes drawn from an urban public school, an urban private school, and a suburban public school. Classes spanned *WAW?*'s target age of second to fourth grade. In-school evaluations included observing in classrooms and computer labs, videotaping selected computer room sessions, taping and transcribing interviews with teachers, and conducting debriefing discussions with both children and teachers. Resulting data were used to revise the prototype software and lesson plans. As described in more detail elsewhere (Kastens, Kaplan, & Christie-Blick, 2001), revisions were made both to the software (e.g., adding voiceovers to text instructions and providing more and faster feedback on students' performance) and to the teacher's guide (e.g., adding more explicit modeling of successful map-use strategies and providing additional assessment tools).

For summative evaluation, children from one class that participated in the *WAW?* curriculum were taken to a section of a parklike campus at the beginning and the end of the school year and asked to complete mapping tasks. One, a sticker-placement task, was modeled after the flag location task designed by Liben and Downs (1989) for classroom use. In the original task, colored paper flags were placed in a three-dimensional cardboard relief model that represented the local area of about 12 × 12 miles. Children were asked to indicate the flags' locations by placing colored stickers on a contour map of the identical region. In the new task developed for *WAW?* field evaluation (Kastens et al., 2001), colored flags were planted at various locations on the campus site, and children were asked to indicate flags' locations by placing colored stickers on a map of the campus area. Again, using terminology described in detail elsewhere (Liben, 1997), the new flag task transformed what was originally a ‘‘representational correspondence’’ task (one assessing children's ability to transfer information from one representation to another) into a ‘‘production’’ task (assessing the ability to transfer information from the real environment onto the representation). In addition, a marker-placement task was developed. After completing the sticker-placement task, children were given a new map on which one (at pretest) or two (at posttest) locations were identified by stickers. Students were asked to place large colored, numbered disks on the ground at the locations indicated on their map. This marker-placement task thus created a ‘‘comprehension’’ task (assessing the ability to transfer information from the map to the real environment).

Sticker placements were scored by assigning points for correct regional placement (e.g., in the right general section), correct category of object (e.g., a building), correct specific object (e.g., the correct building), and correct metric location (within one sticker radius of the precise position). Aggregating across 24 students and 7 flags, scores were significantly higher at the posttest than at pretest. On the marker-placement task, some (but not statistically significant) improvement was found.

Conclusions about the improvement found on the sticker-placement task must be regarded as tentative, however, given that the observed increase in score could have been due to maturation or practice effects rather than to the intervening curriculum. As one way to evaluate the possibility that the improvement in scores could be attributed to maturation, Kastens et al. (2001) also gave the sticker-placement task to children ranging in age from about 5 to 16 years who visited the campus site as part of a community open house. Using data from only those children who reported that they had not been helped by an adult, analyses showed almost no correlation between scores and chronological age. Of course, as noted above (Kastens et al., 2001), a convenience sample of this kind does not provide an ideal comparison group. Furthermore, only the children in the *WAW?* curriculum had the opportunity to visit the site and complete the tasks twice. While it is thus impossible to draw definitive conclusions about the efficacy of *WAW?* from the summative evaluation alone, the methods and data from this work provide a foundation for the fuller evaluation project on which we are now embarking.

Summative Evaluation of Curriculum Materials: Beyond Program Development

As in the case of *WAW?* described above, most evaluation efforts conducted in the context of program development are necessarily limited in scope. In contrast, when evaluation is approached as a goal in its own right, it is possible to address a broader range of issues and to do so more thoroughly. In this final section of the chapter, we discuss five components that we believe are important for evaluating any program that purports to be a developmentally motivated classroom curriculum aimed at enhancing real-world knowledge. In Table 2 we list these components, and in the sections below, we discuss each briefly with illustrations from our emerging *WAW?* evaluation research.

Before doing so, however, we note three issues that underlie and complicate these evaluation efforts. First, it is often difficult to design assessments

TABLE 2
Critical Evaluation Components for Curricula Designed to Teach Real-World Knowledge

- Curriculum Mastery (rote learning and near transfer)
  Does the curriculum benefit students on tasks that are identical to or highly similar to those taught?
- Skill Mastery and Generalization (component skills and moderate/far transfer)
  Does the curriculum benefit students on tasks that tap component skills or alternative instantiations of the target skill?
- Real-World Application (field assessment)
  Does the curriculum enable students to apply what they have learned to the target skill in the real world?
- Classroom Evaluation of Real-World Skills (classroom assessment)
  Does the curriculum provide classroom measures that tap mastery of the real-world target skill?
- Curriculum Adoption and Implementation (teacher variables)
  Under what conditions and how is the curriculum adopted and implemented?

Note. As discussed in the text, implicit in these components is attention to how effects may differ within a diverse student body (including individual and group differences).

in a way that allows them to be used equivalently by students who have and have not participated in the target curriculum. If the assessment tools are not accessible to ‘‘control’’ students, any significant curriculum effects may simply reflect children’s differential understanding of what they are being asked to do or their skill in implementing that understanding. To illustrate using the *WAW?* curriculum, a new assessment might make use of maps and environments that are novel to both experimental and control students. However, if the task requires clicking on the map to show location, or understanding a directional symbol, students in the *WAW?* group might perform better simply because of their greater familiarity with these behaviors and symbols rather than because of a better ability to figure out their location on a map.

Second, there is often a tension between using procedures for research purposes and for pedagogical purposes. For example, from the perspective of obtaining ‘‘clean’’ and ‘‘independent’’ measures of children’s mastery of material, it is best to insist that each child work on his or her own. From the perspective of enhancing student learning and developing children’s team skills, it may be best to permit, and indeed encourage, collaborative work.

Third, and relevant to any developmental or educational research, it is problematic to treat children as if—once chronological age is specified—they are all members of some homogeneous group. A driving question in much of our prior research on spatial, representational, and mapping has been to account for individual and group differences in performance (e.g., see Kastens et al., 2001; Liben, 1991; Liben & Downs, 1986, 1993). We bring these perspectives and goals with us to our current evaluation project. Thus, although in the discussions that follow we refer to ‘‘children’’ collectively, in actuality our research is also designed to identify and understand the age-linked, individual, and group differences that may occur.

Curriculum mastery. The starting point for curriculum assessment is to ask whether children have learned the specific information they were taught. As reflected by the first entry in Table 2, we include here both what might be called rote learning as well as what might be called near transfer. By the former we refer to assessments of whether the student has learned the material virtually exactly as it was presented. By the latter, we refer to assessments of whether the student can extend that learning to materials and situations that are very similar, but not identical, to those encountered during the learning phase itself.

Although one would not want to test *only* this kind of curriculum mastery, tests of rote learning may be useful in assessing whether children used the materials, paid attention, and encoded the content at least at some minimal level. The latter is not necessarily trivial in view of research showing that children may have difficulty remembering information if they lack appropriate cognitive schemata. A dramatic example in the realm of spatial cognition is provided by research on the concept of horizontality in which children are asked to draw a line to show the position of water in tipped containers (Piaget & Inhelder, 1956). Children who do not yet understand coordinate axes find it difficult to reproduce horizontal or vertical lines shown just moments earlier (Liben, 1981b). For these reasons, the assessment of rote learning and near transfer is a valuable first step.

When illustrating this step in relation to *WAW?,* it is probably most instructive to consider how one might assess children's mastery of the skills taught in the software. One obvious possibility is to use the assessments that are built into *WAW?* itself. In ''Are We There Yet?'' the software prints the child's route (which could be scored for directness and success in reaching the destination) and the number of hints requested. ''Lost!'' prints a certificate showing the number of times students placed a mouse click correctly to show where they were, the number of clicks prior to solution, and the total time taken for each problem. ''Add to the Map'' prints maps showing all correctly placed symbols and the number of hints.

As now constituted, however, these exercises are an integral part of the curriculum rather than a set of measures that can be readily used for research purposes. Children typically complete each exercise in group settings in which they receive active suggestions from teachers or other children. While such uses are pedagogically justified (Bransford et al., 1999), they undermine the use of resulting output for research purposes. Our current work is therefore aimed at exploring ways to modify or appropriate one or more of these tasks for research. One might, for example, reserve some of the items for evaluation rather than for classroom use, perhaps adding dependent measures to make tasks more sensitive (e.g., adding a time-to-completion measure to ''Are We There Yet?''). If *WAW?* tasks are to prove useful for comparing

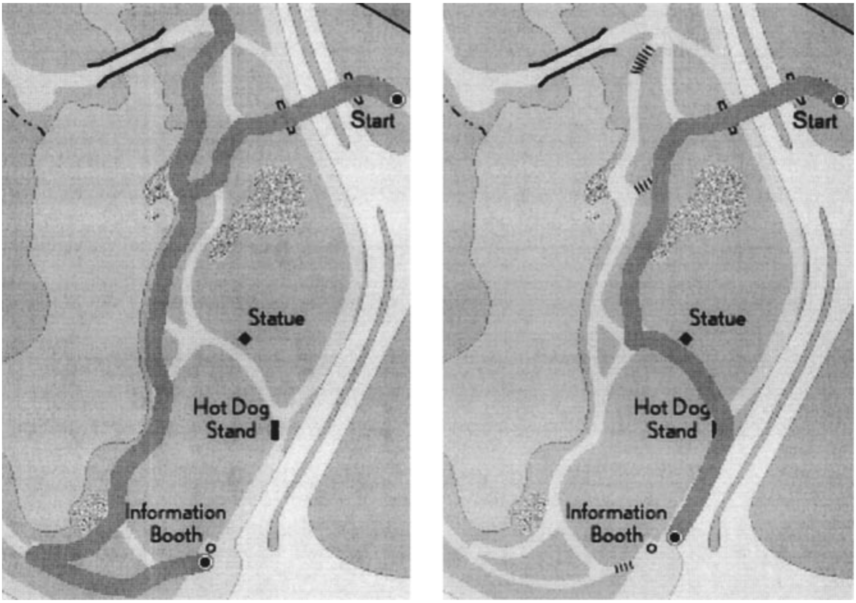


FIG. 6. Sample responses from a pilot test using ‘‘Are We There Yet?’’ as a potential navigational assessment task for people *not* previously exposed to the *WAW?* curriculum. (Left) The indirect route taken by an 8-year-old boy; (right) a direct route taken by an 11-year-old boy.

performance by *WAW?* versus non-*WAW?* children, the tasks must also be useable by children who are not already well versed in *WAW?* software. Our pilot work is encouraging with respect to these issues. For example, as illustrated in Fig. 6, we have successfully used a timed version of ‘‘Are We There Yet?’’ with children who had not been previously exposed to *WAW?* We have also developed and pilot-tested paper versions of ‘‘Add to the Map’’ which allow respondents to place symbols on incorrect locations as well as on correct ones. (In the software, symbols ‘‘stick’’ only at correct locations.) In short, the assessments already included in the *WAW?* curriculum do appear to provide solid foundations on which to build new measures for evaluation research.

However, even if one found that children who had participated in the *WAW?* curriculum perform better than non-*WAW?* children on these assessments, the (hypothetical) advantage might simply reflect greater familiarity with the stimulus materials. The possibility that *WAW?* children are learning a set of view-specific images rather than more general strategies for relating spaces and maps is given credence by the finding that even adults rely upon stored, view-specific representations of environments when they are asked to reason about a known space (e.g., Roskos-Ewoldsen, McNamara, Shelton, & Carr, 1998; Shelton & McNamara, 1997). Given this possibility, it is especially important to use entirely new materials and even new kinds of tasks to evaluate the impact of the curriculum. We thus turn to the second component of evaluation listed in Table 2.

Skill mastery and generalization. The second component is aimed at evaluating whether the curriculum affects children's performance on tasks that are superficially different from the material used in the curriculum, but that are believed to tap the same target knowledge or its subskills. An analogy from studies on children's mental models of Earth (Vosnaidou & Brewer, 1992) provides a telling example. When elementary school children were asked about the shape of Earth, they gave correct verbal and graphic answers almost universally, saying or drawing something round. However, when asked questions that tap understanding of the Earth's shape in novel ways, many of the younger children gave responses suggesting that their earlier responses were based on rote learning. For example, when asked to show where the sun and stars would be, some children drew stars only ''above'' the circle; when asked to show where people live, some children drew people inside the circle. This program of research provides an excellent illustration of why it is important to develop assessments that differentiate between rote and conceptual learning.

An illustrative assessment task that we are developing for our *WAW?* evaluation project is one in which respondents are asked to link eye-level perceptual experiences with abstract maps, but using a different task from that used in *WAW?* Specifically, participants are shown eye-level photographs of an environment (a static analog to the video images of the *WAW?* software) and asked to use an arrow sticker to mark the photographer's location and orientation on a map of the environment (an analog to the mouse clicks for showing location in the ''Lost!'' mode of *WAW?*). To test the range of generalization, we are varying the kinds of environments (e.g., a playground, a furnished room, and a university campus) and the kinds of maps (nadir and oblique perspective). Figure 7 shows two sample photographs and Figs. 8 and 9 show composite maps of responses to these items by samples of adults and fourth-grade children.

Coding schemes are also under development. Because determining the correct response draws upon not only understanding how to relate a person's-eye-view image to a vantage point shown on a map, but also understanding the photographic process per se (e.g., was a zoom lens used?), the pilot scoring system allows a range of arrow placements to be counted as correct. For example, for a response to the room photograph shown in Fig. 7 to be scored as correct, the arrow must be behind the table (because the entire table is seen in the photograph), but the specific distance behind the table is unspecified [because camera distance can be determined only if the respondent has available (and understands) relevant information about the camera lens]. Assessments like these are valuable for exploring whether curriculum benefits generalize to other representational tasks, and they may be helpful for

FIG. 7. Sample of room and campus photographs used for items in the ‘‘photo-map’’ task. (Actual photographs were in color.)

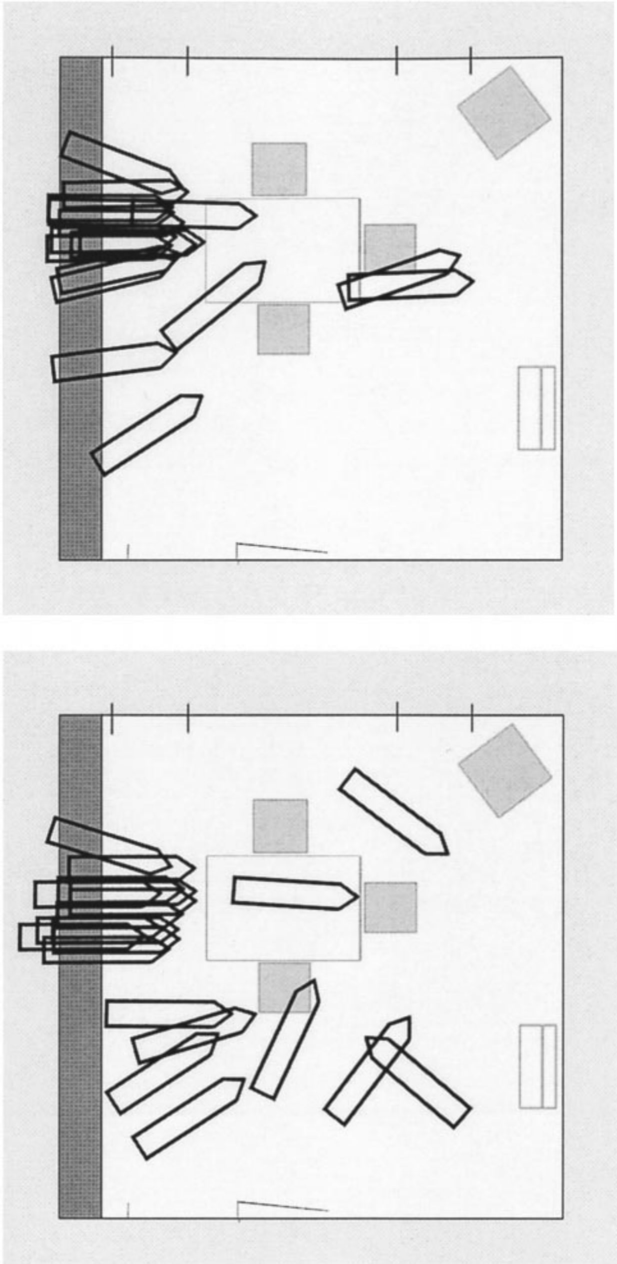


FIG. 8. Composite maps showing arrow placements by college students (top) and fourth-grade students (bottom) for room photo shown in Fig. 7. (The map actually used in the task was more detailed and contained a map key.)

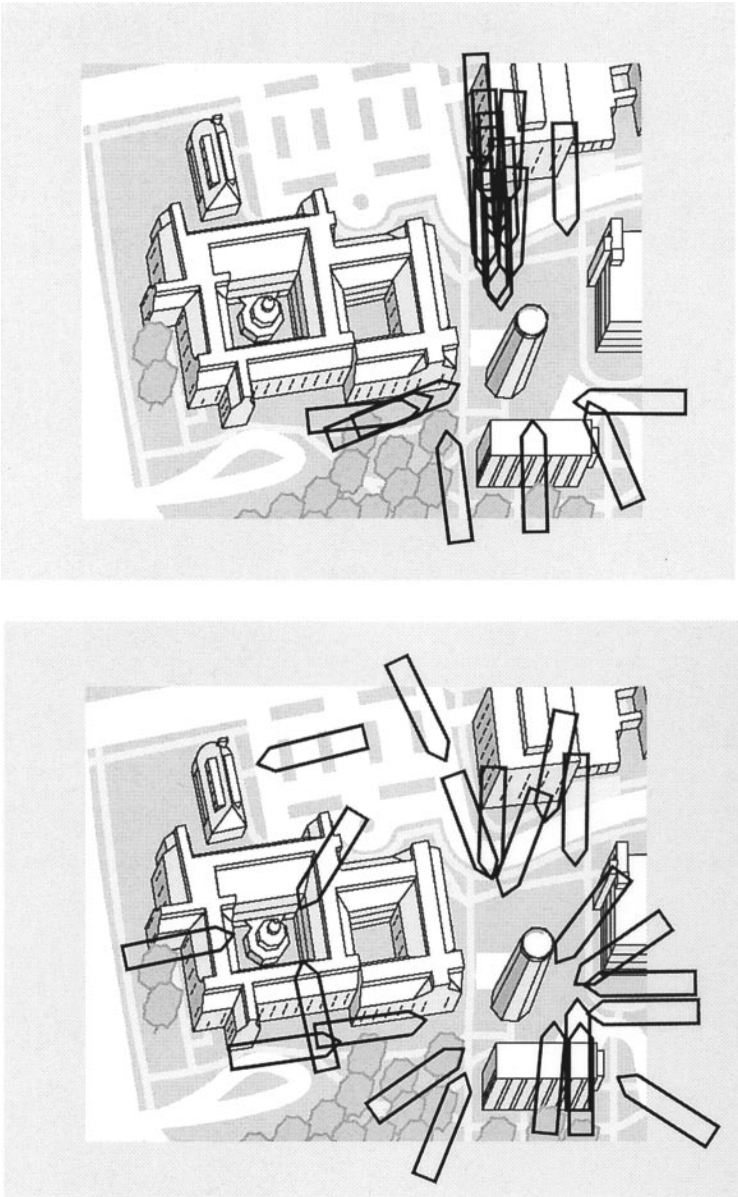


FIG. 9. Composite maps showing arrow placements by college students (top) and fourth-grade students (bottom) for campus photo shown in Fig. 7.

quantifying the relative importance of specific categories of misconceptions, for example, left–right confusions (e.g., see the arrows placed by children in Fig. 9 for the campus photograph shown in Fig. 7, some of which suggest right–left confusions). They cannot, however, speak to whether benefits generalize to the real world, an issue that is the focus of the third evaluation component.

Real-world application. The third component distinguishes evaluation efforts for programs designed to enhance ''real-world knowledge'' from those designed to enhance more traditional ''book learning.'' The latter may quite reasonably be evaluated by examining students' performance on multiple-choice or essay tests covering the material taught in the curriculum unit. The former requires some actual real-world assessment of the kinds of skills that are the intended target of the curriculum.

To illustrate using *WAW?*, an ideal real-world assessment might involve taking children to an unknown area, providing a map, and testing whether children are able to navigate from one location to another. They might be shown their starting location (as on a *You Are Here* map) and asked to reach a destination, or they might be dropped at some unknown location and asked to find their way to another location (e.g., the park entrance). These tasks are, of course, what the ''Are We There Yet?'' and the ''Lost!'' modes are meant to simulate.

Because field assessments, like *in situ* education, are constrained by practical considerations (e.g., available field sites; cost of transportation; difficulty of obtaining maps; coding challenges with more open-ended tasks; high personnel needs; and, above all, safety), ideal assessments of this kind may be used during formative evaluation to help to generate hypotheses about children's strategies (as in *WAW?*, see Kastens et al., 2001), but they can rarely be used for summative evaluation. Thus, field tests, too, are usually only approximations of the ideal. For *WAW?*, several viable field tasks have been developed. These include the arrow placement task used with college students (Liben & Stevenson, in preparation, see Fig. 1) and the sticker location and the marker-placement tasks used in the *WAW?* summative evaluation (Kastens et al., 2001, see illustration in Fig. 10). For our new evaluation research, these tasks are being modified slightly (e.g., increasing the number of marker-placement items) and are being given to children who have *not* participated in the *WAW?* curriculum. This will allow us to discriminate pretest to posttest improvements that may be due to the curriculum from those that may be due to maturation or repeated testing. In addition, new field sites and maps are being prepared to test whether curriculum advantages (if any) are restricted to natural, parklike environments like those of *WAW?* or if they also generalize to other kinds of environments and maps.

Throughout the process of developing field assessments, it is important to be vigilant that even as tasks are made practical, they simultaneously remain connected to the real-world tasks of our daily and professional lives. The

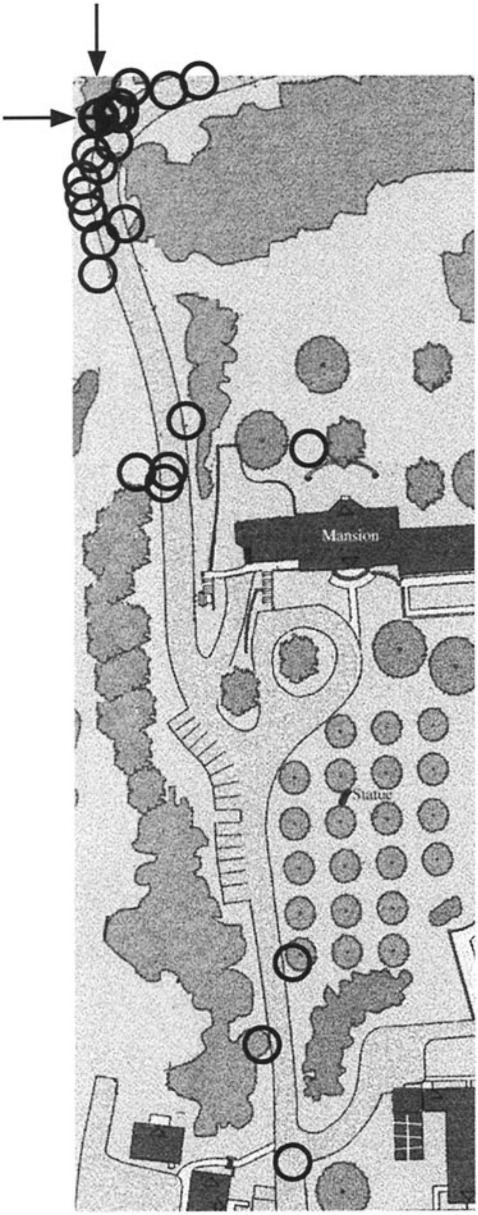


FIG. 10. A section of the map used in the field test showing a composite map of *WAW?* students' posttest responses for one flag. (Correct location is indicated by intersection of arrows shown on the left and top borders; actual map was in color.)

sticker-placement task, for example, is similar to what a field geologist or ecologist would do when mapping rock or vegetation types onto a base map of the field area. The place-marker task is similar to what a hydrologist might do when going to four predesignated sites to take water samples.

The field assessments just described are essential for evaluating the effectiveness of a curriculum aimed at developing real-world skills. However, even if evaluation research shows that a curriculum program is effective in enhancing students' real-world skills at the level of the group, there remains a need to monitor achievement at the level of the individual student, the focus of the fourth component listed in Table 2.

Classroom evaluation of real-world skills. The goal of the assessments already discussed is to determine if the *curriculum* is an effective program for teaching the target skills. Results from this aspect of the evaluation research are needed to decide whether the particular curriculum under consideration is a successful one, including whether it is effective for various groups of learners (e.g., girls and boys and urban and rural students). Results from such evaluations affect curriculum adoption and perhaps curriculum revision. But in addition, it is also important to provide the teacher with tools for monitoring whether individual *students* have achieved the target skills. Thus, the fourth component listed in Table 2 addresses the question of whether the curriculum offers the teacher appropriate student assessments. Many of the same issues discussed with respect to evaluating the curriculum as a whole apply to evaluating students as individuals. Most importantly, even though the goal is to enhance students' real-world skills for use in the real environment, it is unrealistic to insist that teachers assess students' achievements in the field. Thus, another component of evaluation that is essential for curricula aimed at teaching real-world skills is to develop practical classroom assessments that are predictive of the student's ability to implement the target skills in the field.

Again, to illustrate using *WAW?*, it may be possible to turn the research versions of some of the assessments discussed above (e.g., see Fig. 6) back into individual assessments. Our pilot work with college students has shown significant correlations between performance on tasks like these and performance on tasks in the real world (such as the map location task illustrated by Fig. 1). Although in an absolute sense the correlations found in pilot work are only modest (with correlation coefficients in the middle .30s), they are encouraging when contrasted to the complete absence of a correlation between children's performance on the *WAW?* map quiz given in the classroom and performance on the sticker-placement task given in the field ($r = .05$, see Kastens et al., 2001). In short, evaluation must also address the utility of the student assessments that are offered to teachers as part of the curriculum package.

Curriculum adoption and implementation. The final component listed in Table 2 concerns curriculum adoption and use. In some sense this may be the single most important component because even the best curriculum cannot be effective if it is not used. Almost all adoptions are influenced by budget and the availability of appropriate equipment (e.g., computer facilities). Most adoption decisions entail domain-specific issues as well. For example, decisions about a curriculum such as *WAW?* are likely to be affected by district- or state-level decisions about whether geography is taught as a free-standing subject (a decision that influences how much class time is devoted to map education). It is also likely to be affected by the national testing context, particularly given the current emphasis on high-stakes testing. To the degree that geography education and spatial thinking are viewed as an important part of the national educational agenda and thus find their way into national assessments, curricula such as *WAW?* are more likely to be adopted. From this perspective, it is encouraging that geography was included in *Educate America Act* (Public Law 103-227), that the National Academy of Sciences (2001) recently constituted a National Research Council Committee on ‘‘Support for Thinking Spatially: The Incorporation of Geographic Information Science Across the K-12 Curriculum,’’ that geography assessment is now regularly included in the National Assessment of Educational Progress (Persky et al., 1996), and that geography was recently added to the selection of advanced placement tests offered by the Educational Testing Service.

While others are studying the impact of institutional level factors, our own research will concern factors that may affect adoption decisions by individual teachers. In particular, our work is designed to investigate whether teachers' own levels of spatial skills and personal experiences with maps are related to their interest in using *WAW?* with their students. This work will only begin to explore the uncharted territory of how decisions about map curricula are made, but also serves as a reminder of the value of extending curriculum research beyond traditional summative evaluation.

SUMMARY AND CONCLUSIONS: WHERE HAVE WE BEEN AND WHERE ARE WE GOING?

In this article, we have presented a series of arguments for why the navigational use of maps is important for the developing child. Skills developed for map navigation are important not only because maps are often useful for getting around our real world, but also because these skills may facilitate basic representational and spatial concepts. We have argued that although map-navigation skills would, in principle, be good candidates for *in situ* education, the realities of our culture and educational system make the ‘‘real world’’ venue a difficult one. It is for this reason that we have argued for the importance of developing effective curricula for classroom use. After reviewing an array of psychological and educational research related to map-based navigation, we turned to a description and discussion of the *WAW?* curriculum (Kastens, 2000). This focus allowed us to highlight the ways in which developmental psychology can inform a map-navigation educational curriculum at both a domain-general level (the role of action-based learning) and a domain-specific level (the role of children's developing spatial concepts). The example of *WAW?* also allowed us to illustrate some of the constraints that commonly plague summative evaluation and to endorse the importance of evaluation research occurring separately from curriculum development. We ended by offering a list of components that we believe should be addressed when evaluating any developmental curriculum for teaching real-world knowledge, illustrating these components by reference to the initial stages of our own emerging *WAW?* evaluation research.

We close with the truism that if you do not care where you are going, any road will take you there. But if you do know where you want to end up, two things are essential. First, you must know where you are starting. Second, you must select (and have the skills needed to follow) a route. Those of us committed to helping children master both of these component skills must understand the children who are embarking on the journey. Developmental theory and research—which provide that understanding—are thus essential ingredients for designing educational programs that can lead children to their real-world destinations.

APPENDIX

Lesson 9 from the Teacher's Guide of *Where Are We?*
(The complete guide is available at
http://www.LDEO.columbia.edu/WAW/guide/bindercover.html).

Lesson 9: The Compass Rose

Summary

Students use a compass rose in the classroom and on the computer map to figure out the direction someone is facing or moving.

Goals

- To teach students to use a compass rose in conjunction with a compass
- To have students differentiate between North as a region and north as a direction
- To show students when to use north/south/east/west rather than right/left

Desired Student Outcomes — Students Will:

- Identify a compass rose and its purpose
- Use a compass rose to determine a direction on the map
- Appreciate the usefulness of a compass rose
- Understand what a compass is used for in mapping and navigation
- Look forward to learning how to use a compass

Time Required

- Two to three class periods

Materials

- *Where Are We?* CD-ROM(s)
- *Where Are We?* figurine
- *Where Are We?* poster map
- *Where Are We?* student map
- compass
- computer monitor
- computers
- masking tape
- Location Cards (on page 73); photocopy enough for half the class
- north, south, east, west signs (made by teacher)
- large paper compass rose (made by teacher)

Vocabulary

- compass
- compass rose
- north, south, east, west
- cardinal directions
- intermediate directions
- relate

Before Using the Computer

1. Introduce cardinal directions.

- *Today we're going to talk about the cardinal directions, "north, south, east, and west." What do you know about them?*
- *Which direction is north? How do you know?*

Elicit that you need a compass, which has a needle that always points north, or you need to look at the sun's path and remember that it rises in the east and sets in the west, or you can use a street map of your neighborhood with a compass rose on it. If you use the direction of the sunset and sunrise, you might want to discuss that although it appears that the sun is moving, it is really due to the rotation of the earth.

Ask a child to place the large paper compass rose on the floor matching its N with the real north. Place a compass on top of the compass rose to check that the norths are aligned.

Tell them it's a compass rose. Ask everyone to face north, then south, etc.

Ask students where you should put the "north," "south," "east," and "west" signs. Put these up on the appropriate walls of the classroom. More able students may want to add signs to show the intermediate directions of northeast, etc. If you are using a compass in the classroom, remember that it is affected by metal objects.

2. Show students the poster map and discuss the compass rose.

- *Where is the compass rose on this map?*
- *When do you use a compass rose?*
- *How is it different from a compass?* (A compass rose shows the directions on the map; a compass shows directions in the real world.)

Place a figurine on the poster map. Show the figurine walking on a path (near the top of the map) in a northerly direction.

- *If this were you, in which direction would you be walking?*

Repeat, moving the figurine in a northerly direction along a path near the bottom of the map. After you are confident that they understand that the figurine is still walking north, even though it is in the southern region of the map, try some of the other directions. You may want to include some of the intermediate compass directions such as "southeast." (If students are confused, see "A Common Misconception: North as a Region Versus North as a Direction," page 70.)

Hand the figurine to a student:

- *Put the figurine on the map and have it walk northwest.*

Repeat several times with other compass directions. (If students are confusing east/west directions with right/left directions, see "A Common Misconception: Right/Left Versus North/South/East/West," on pages 71–72.)

3. Students give directions using north/south/east/west.

Divide students into pairs. Give partner A a location card and tell her or him not to show it to partner B. Give each student a *Where Are We?* map. Partner A uses compass directions to direct partner B to the location on the card. Partner B lets his or her fingers do the walking on the paper map. Partner A should immediately notify partner B if he or she starts to go wrong while trying to follow the directions.

4. Wrap up.

- **How did it go? Were you able to follow the compass directions?**

Second Session

At the Monitor

1. Launch *Where Are We?*, sign in, and click Are We There Yet? mode. Point out the compass rose in the lower portion of the map, and the compass on the forward arrow.

- **What's the difference between the compass rose and the compass?** (The compass rose never changes. It shows all the directions that exist. It is part of a map. The compass shows you the direction you are facing at this moment. The compass turns when you turn.)
- **How can you use the compass and the compass rose to help you find your way?** (When you turn left or right, the compass changes to tell you the new direction you are now facing. Match the direction with the compass rose to check your direction on the map.)

Place your finger on the map to show the starting position and direction.

- **My finger on the map is like the red dot and arrow; my finger is showing where we are located and what direction we are facing.**
- **Now let's move to a new position.**

Click the Move Forward arrow. The red dot and arrow disappear.

What direction are we looking now? (Students look at the compass on the forward arrow.)

- **Now look at the compass rose to figure out what direction that is on the map. Who can show us on the map where we are and which direction we are facing?** (Volunteer places a finger on the map to show current location and facing direction. Ask volunteer to explain.)
- **Let's see if you're correct...**

Click Hint. The red dot and arrow should be at the same place and pointing in the same direction as the student's finger. Repeat this activity as time allows.

At the Computer

1. Give directions for student activity at computers.
    - Now walk around in the video. After each move, look at the compass to see which way you are facing. Find that direction on the compass rose. Put your finger on the map to show where you think you are. Point the direction you think you are facing. Use the Hint button to see if you're right.
2. Wrap up.
    - How did you do? What made you successful?

Extension

- Draw a picture of your house. Draw the sun rising in the correct location. Which side of your house has the sun shining on it first? Draw a compass rose. Does the east point to the rising sun?

A Common Misconception: North as a Region Versus North as a Direction

The Problem

Students often have trouble understanding that north, south, east, and west refer to a direction in which a person or thing faces, points, or moves, and that the same words can also refer to a place, location, or region. For example, we say "North America," or the "East Side" of our city. We also say, "The river flows north," or, "the car is driving east."

Typical Symptoms

- When asked to place a figurine on the map facing northeast, the student places the figurine in the upper right corner of the map facing any arbitrary direction.
- The student notices the *Where Are We?* compass saying "N," puts her hand on the upper half of the map, and says, "We must be up here someplace."

Teaching Strategies

1. In the classroom, with the cardinal directions on the appropriate walls, play "Simon Says."

- Simon says, "Face west."
- Simon says, "Walk 3 steps east."
- Simon says, "Walk to the north end of the room."
- "Face north."

Be sure to intersperse instructions in which the compass word describes a direction to move or face with instructions in which the compass word refers to a region or quadrant of the room.

2. When working with a figurine on the poster map, place the figurine in the northern section of the map. Orient the pointer toward the south. Ask students:

- **In which region of the map is the person?** (North.) **Which direction is she facing?** (South.)

Repeat with other combinations of direction and region.

3. When demonstrating any of the modes of *Where Are We?*, or when working with individual students having the symptoms of this misconception, ask:

- **What direction are we facing?**
- **What direction are we moving?**
- **What quadrant (or region) of the map are we located in?**

A Common Misconception: Right/Left Versus North/South/East/West

The Problem

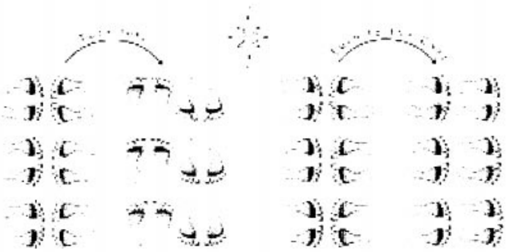
Students get confused between relative directions (right and left) and compass directions (north, south, east, west), or they use one kind of direction when the other would be more appropriate.

Typical Symptoms

- Students think of the "turn right" button as the "east" button.
- Students can find their way when they are moving northward (when right equals east, and left equals west), but they become confused when moving southward, eastward, or westward.

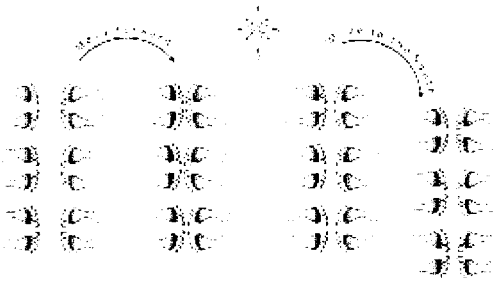
Teaching Strategies

1. In the classroom, with the cardinal direction signs on the appropriate walls, have students stand up in two lines that face each other. Ask all students to turn to the left. Each line will be facing a different direction (see diagram). Ask students to face each other again. Next, instruct students to stand so they are facing east. All students will be facing the same direction (see below).



- **What happened when everyone turned left?** (Ended up facing different directions.)
- **What happened when everyone turned to the east?** (All ended up facing the same direction.)

Ask students to face each other again. Instruct students to move forward. They will be closer together (see below). Now tell students to move south. Both lines should move in the same direction (see below).



- **What happened when everyone moved forward?** (Moved in different directions.)
- **What happened when everyone moved south?** (All moved in the same direction.)
- **Can you think of any reason why you might want to use "north" or "east" rather than "left" or "right" directions sometimes?** (When a compass direction was given, everyone moved or turned in the same direction. If you don't know which way the person is facing to start with, you can make sure he or she will move or turn in the appropriate direction if you use compass directions.)
- **Can you think of any circumstances when you might prefer to use "left" or "right" rather than "north" or "south" directions?** (If the person doesn't have a map or any other way of orienting himself/herself relative to the compass.)

2. When demonstrating any of the *Where Are We?* modes, or when talking with individual students who demonstrate this misunderstanding, ask:

- **What direction am I facing?** (East.)
- **What should I do if I want to face south?** (Turn right.)
- **Now what should I do if I want to face west?** (Turn right again.)
- **What should I do if I want to face south again?** (Turn left.)
- **What direction will I be facing if I turn right?** (West.)

Location Cards

Start: Gazebo

End: Bridge

Start: Statue

End: Gazebo

Start: Nature Sanctuary Entrance

End: Tunnel

Start: Bridge

End: Hot Dog Stand

Start: Bridge

End: Information Booth

Start: Information Booth

End: Nature Sanctuary Entrance

Start: Information Booth

End: Gazebo

Start: Gazebo

End: Statue

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