

# The Development of Children's Spatial Knowledge: Implications for Geographic Education

One of the many challenges facing the education system today is providing children with a better understanding of geography. Increasingly, cartographers and educators have turned to developmental psychologists for information about how children's spatial cognitive development influences their ability to understand and learn about the spatial relations on maps. Central to the process of learning and remembering spatial relations is the ability to organize locations within some kind of spatial structure. Recently, the role that hierarchical organization plays in remembering and reasoning about locations has received increasing attention within the field of cognitive psychology. Studies have shown that both children and adults alike tend to organize locations into regions with nested levels of detail. For example, the location of a toothbrush might be remembered as on the second shelf in the medicine cabinet in the bathroom upstairs, or the location of Iowa City might be known as in the state of Iowa in the Midwest region of the United States. There are, however, limitations in children's ability to make use of hierarchical spatial structures; this has important implications for cartographic education. As a result, younger children may require more visual aids and explicit organizational frameworks when learning and communicating information about locations. The ideas and suggestions presented here about the relations between children's spatial cognitive development and their understanding of geography are aimed at fostering further collaboration between cartographers and developmental psychologists.

The American education system has experienced increasing pressure in recent years to provide children with a better understanding of geography. One integral aspect of geographic education is, of course, to teach children about the spatial relations among geographic locations. Quite naturally, this raises the issue of how one might best teach children of different ages about the spatial relations represented on maps. In response to this problem, educators increasingly have turned to developmental psychologists for information about how children's cognitive development influences their ability to understand and learn about spatial relations. One central aspect of spatial cognition that has many implications for geographic education is how children and adults organize and remember spatial information. In particular, how do children and adults extract and organize spatial information from maps and the environment, and how does this affect their ability to remember and communicate this information? The goal of this paper is to review the psychological litera-

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## INTRODUCTION

ture on the structure of spatial knowledge and to suggest possible implications for geographic education. The paper is organized into three major sections: the first outlines recent theory about the nature of spatial representation; the second concerns the role of spatial clustering in memory for locations; and the third focuses on hierarchical organization of spatial information in communication about locations.

## REPRESENTATION OF SPATIAL INFORMATION

The ability to organize locations within some kind of spatial structure is fundamental to the process of learning and remembering spatial relations. Without this structure, remembering the locations of the countless objects and places encountered everyday would become an insurmountable task. By organizing knowledge of location, memory demands are lessened because locations are not treated as isolated pieces of spatial information. There is emerging consensus within the field of adult spatial cognition that this knowledge of locations is organized hierarchically, that is, as regions with nested levels of detail (Eastman 1985; Hirtle & Jonides 1985; McNamara 1986; McNamara, Hardy, & Hirtle 1989; Sadalla 1988; Stevens & Coupe 1978). Within this structure, individual locations are connected to each other through their common membership within a region. Likewise, regions can be grouped on the basis of their belonging to larger, more inclusive regions. Individual locations can be organized into spatial units on the basis of physical barriers or perceptual boundaries (e.g., walls in a room or streets in a city) that mark divisions between spatial units. Likewise, locations that are proximal to a salient landmark or reference point can be clustered together into a spatial unit, for example, the Great Lakes region. In both cases, spatial organization is grounded in perceptual experience, either with encountering barriers and landmarks while

moving through the environment, or through experiences with viewing boundaries represented on maps.

This framework can be applied to knowledge of locations in everyday environments, as well as to knowledge of locations on a much larger geographic scale. For example, the location of a toothbrush might be known as on the second shelf in the medicine cabinet in the bathroom upstairs. Similarly, as Figure 1 illustrates, one might think of Iowa City as a city in the state of Iowa, which in turn is part of the United States, which is also a region in North America. Spatial clustering and hierarchical organization are also reflected in the ways in which locations and geographic regions are represented on maps. Although maps clearly preserve some metric spatial relations, they

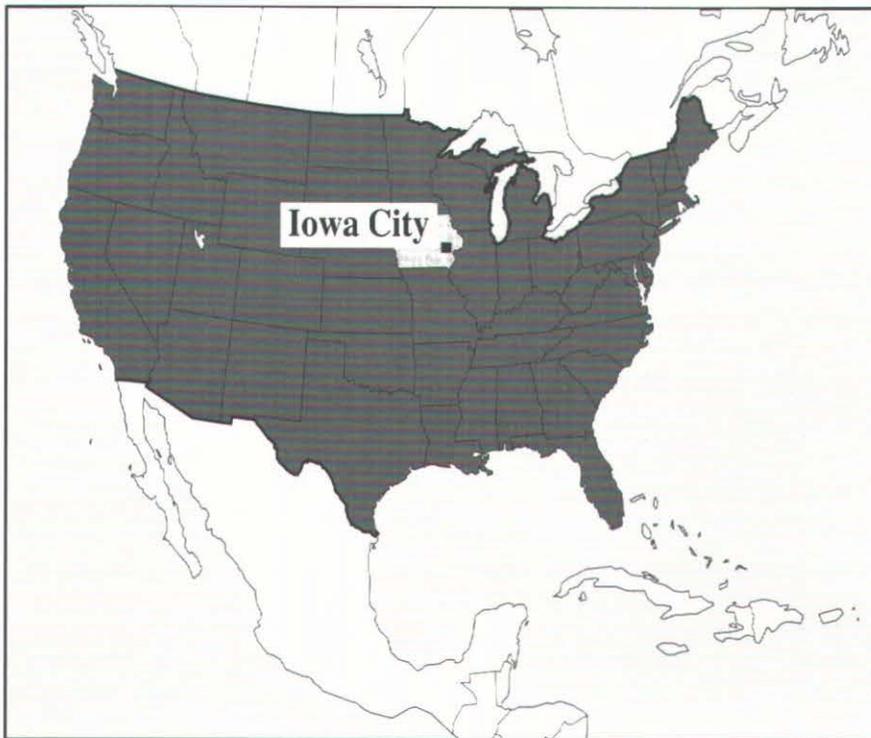


Figure 1: Hierarchical organization of spatial regions.

also take great pains to show boundaries between states and countries. Hierarchical organization is also usually present in maps, often taking the form of heavier, darker lines to represent boundaries of major subdivisions, and lighter, thinner lines to show the smaller regions that make up

the larger ones. The remarkable similarity between mental and cartographic representations of space underscores the idea that spatial clustering and hierarchical organization play an important role in our understanding of distance and spatial relations. Eastman (1985), in fact, has shown that adults have a strong bias to chunk information learned from maps, and that this chunking often takes the form of grouping locations into a hierarchy of spatial regions.

What evidence exists that supports the notion that individuals mentally organize locations into spatial units? One technique for investigating this issue is to measure how quickly individuals can respond to objects that are located in the same or in different spatial regions. In such studies, individuals read the names of two objects presented one after the other on a computer screen. Their task is to make a judgment about the second object as quickly as possible. For example, subjects may be asked to judge whether or not the object was present in the collection of objects located in the layout they had previously learned. The rationale behind this approach is that if locations from the same spatial region are more closely associated in memory, then the time required to respond to a object should be faster if it is preceded by the name of an object from the same region than from a different region. A number of these so-called spatial priming studies have shown that adults group locations by region even when the region is defined only by tape on the floor (e.g., McNamara 1986; McNamara, Hardy, & Hirtle 1989). Thus, one object will facilitate responding to another object from the same region more readily than one belonging to a different region. This occurs even if the object from the different region is physically closer to the target object than is the one from the same region as the target object.

The errors adults make when judging spatial relations also underscore the importance of containment relations between spatial regions. For example, Seattle is usually judged to be farther south of Montreal, when in fact it is farther north (Stevens & Coupe 1978). Presumably, this error occurs because individuals rely on the north-south relations between the larger geographic regions to judge spatial relations between locations contained within those regions. Similar studies with children have also shown that spatial subdivisions exert a powerful influence on their memory for locations (e.g., Acredolo & Boulter 1984; Allen 1981; Kosslyn, Pick & Fariello 1974). When asked to make spatial judgments about individual locations belonging to different spatial regions, for example, even 6-year-olds tend to rely on the overall spatial relations between regions rather than on the actual spatial relations between the individual locations (Acredolo & Boulter 1984). Similarly, Allen (1981) found that 7- and 10-year-olds and adults tend to partition routes into subdivisions, and use these subdivisions to make distance judgments about locations along the route. In particular, children and adults often judged locations from two adjoining subdivisions as more distant than locations within the same subdivision even when the locations within the same subdivision were more physically distant than the locations from adjoining subdivisions.

These studies support the argument that subjective spatial organization plays an important role in our perception of distance and memory for spatial relations. It is important to point out, however, that the tendency to group locations into spatial regions can be a double-edged sword for education. In one sense, such groupings help children simplify the problem of remembering locations and making spatial inferences. On the other hand, both children and adults are likely to make false judgments and inferences about locations when spatial organization comes into

#### THE ROLE OF SPATIAL CLUSTERING IN MEMORY FOR LOCATIONS

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conflict with actual metric relations. Therefore, it is important for teachers to be aware of locations that children are likely to misrepresent.

Another source of evidence for how children and adults organize their knowledge about locations is the order in which they recall information about objects and their locations. Again, the rationale behind this approach is that if locations within the same region are more closely related than are locations from other regions, then locations from the same region should be clustered together in recall. Studies by McNamara and his colleagues have shown that the order in which adults recall locations indeed reflects regional organization (e.g., Hirtle & Jonides 1985; McNamara, et al. 1989). For example, adults recall buildings and businesses from one area of their home town before recalling those in adjoining areas.

Several kinds of measures have been employed to investigate children's use of spatial clustering to organize their recall of objects and locations. In general, these studies have revealed that the ability to group items spatially improves over the course of childhood. Research of categorical knowledge in very young children using the sequential touching technique has shown that 20-month-olds respond categorically to classes of objects bound together by spatial and functional relatedness (Mandler, Fivush, & Reznick 1987). In this study, toddlers were presented with a tray containing kitchen things (pan, spoon, cup, and plate) and bathroom things (toothbrush, soap, toothpaste, and comb), and were encouraged to manipulate the objects. Previous studies have shown that the order in which young children touch or manipulate objects is a good indicator of their knowledge and perception of the relations among the objects. Basically, by touching most or all of the objects from one category before touching those from the other category, young children are demonstrating their ability to group the objects. The finding that 20-month-olds systematically touched objects belonging to the kitchen and the bathroom suggests that even very young children have the capacity to remember spatial groupings. It should also be noted, however, that children may have been relying on other sorts of connections between the items such as temporal and functional relations. Further research is needed in this area to examine the early emergence of children's understanding of spatial groupings. Nonetheless, these findings suggest that the ability to remember spatial clusters may be in place very early in development.

Studies of young children's ability to carry out organized searches for objects have also provided useful information about children's sensitivity to spatial organization. The basic method used in these studies is to observe the order in which children search for a set of objects that they previously saw hidden in several locations. One can then determine the extent to which the retrieval order reflects spatial clustering. This approach has proven useful for understanding developmental changes in children's ability to cluster locations, and how spatially organized searching is related to more complex tasks such as communicating about a set of locations. This method may also offer alternative approaches to teaching children about spatial relations, for example, drawing parallels between familiar activities such as searching for objects in large-scale spaces and traditional classroom activities such as searching for locations on a map.

Clearly, children as young as four years are capable of spatially organized searches in situations where there are relatively few locations that are subdivided into a small number of spatial clusters. For example, Wellman, et. al (1984) found that 4- and 5-year-olds minimized the number of traverses they made between two clusters of locations while retrieving Easter eggs they had previously seen hidden in five buckets on a

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playground. Three-year-olds, however, did not exhibit such clustering in their retrieval patterns. Similarly, Cornell and Heth (1986) found that both 5- and 7-year-olds hid objects in spatial clusters and tended to search those clusters exhaustively when later retrieving the objects. These results suggest that as children grow older they become increasingly able to use spatial organization to guide their activity within the physical environment.

Another related area of research that has implications for geographic education is the use of spatial clustering strategies in recall. The use of location to facilitate recall dates back to the time of the Greeks who developed the *method of loci* (Bower 1970; Yates 1966). To aid recall of speeches, Greek orators mentally placed each part of their speech at a location along a well-known route. When it came time to give the speech, the orator had only to imagine moving along this route to recall what he wanted to say next. Until recently, however, there has been little research on how adults and children use location to organize recall of objects and other non-spatial information. More typically, research on organizational strategies has focused on the use of categorical clustering strategies. It is well-documented, for example, that older children and adults can maximize their ability to remember information by grouping items belonging to the same category. In other words, if given a scrambled list of items to remember such as *bed, dog, chair, shirt, horse, hat, table, and cow*, children recall more if they group items by category (*bed, chair, table/ dog, horse, cow/ shirt, hat*).

More recently, the notion of recall organization has been expanded through investigations of the use of spatial clustering strategies in recall. As illustrated in Figure 2, recall of many objects encountered in everyday spaces can be organized either categorically or spatially. One issue this raises is which recall strategy do children and adults prefer to use when both are simultaneously available? Plumert (1993) investigated this question by asking 10-, 12-, 14-, 16-year-olds, and adults to recall as many pieces of furniture from their home as they could remember. Making a furniture inventory from memory is a particularly useful task for investigating spatial and categorical organizational strategies because furniture items can be grouped either by category (tables, chairs, beds, dressers), or by spatial region (kitchen, living room, bedroom, laundry). Quite surprisingly, analyses of the order in which subjects listed their furniture

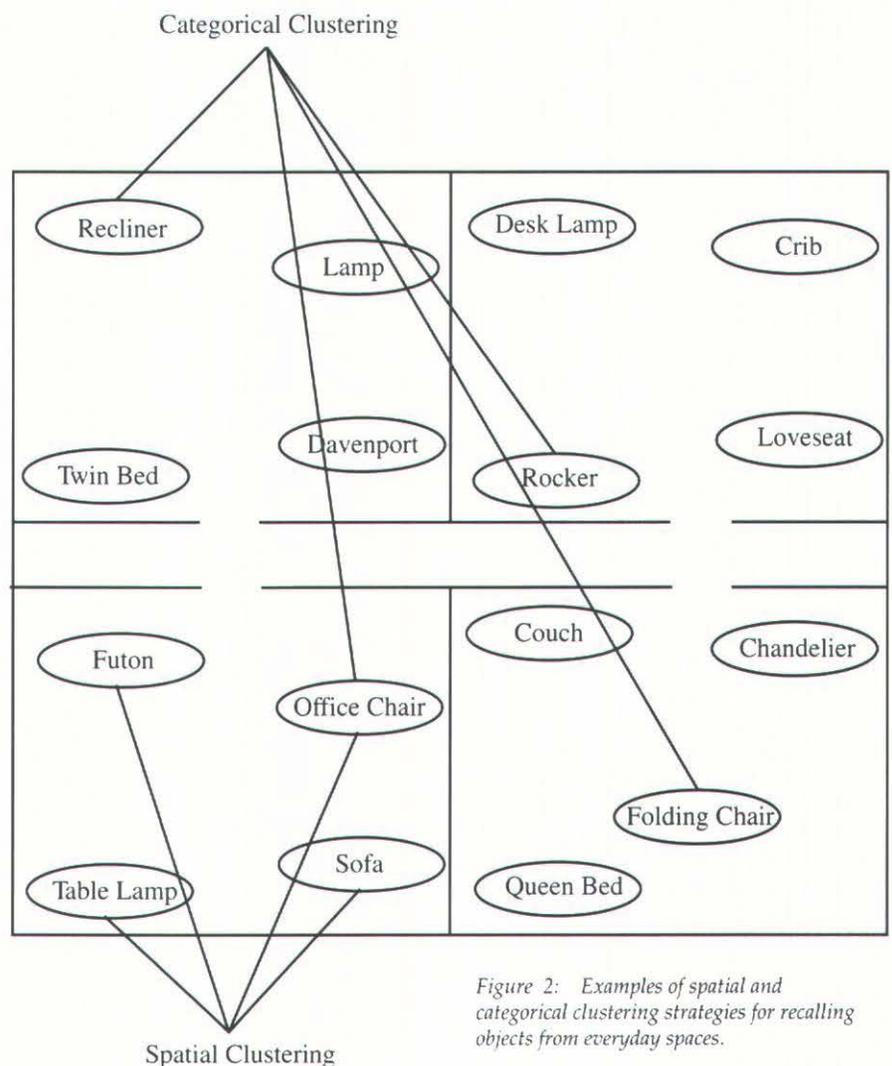


Figure 2: Examples of spatial and categorical clustering strategies for recalling objects from everyday spaces.

revealed that 10-year-olds grouped furniture items on the basis of categorical relationships, for example, *beds, chairs, couches, dressers*. Adults and 16-year-olds, on the other hand, relied almost exclusively on spatial organization, that is, most of them listed furniture room by room. The 12- and 14-year-olds, however, exhibited a mixture of categorical and spatial organization in their recall. Moreover, spatial clustering scores for the transitional groups (i.e., 12- and 14-year-olds) were significantly positively correlated with the number of furniture items they generated.

These findings raise the question of what factors might induce younger children to employ spatial organization in their recall. Although little research exists on this problem, one factor found to mediate the use of spatial clustering strategies by younger children is whether or not the recall task involves a spatial component. Plumert (1991), for example, showed that the presence or absence of a spatial component in the task had a major influence on the type of organizational strategy children used. Specifically, when the task was to recall only the names of objects, the majority of 10- and 12-year-olds used category membership to organize their recall. In contrast, when the task was to recall the objects with their locations, the majority of children abandoned categorical organization and instead clustered objects from the same room together. Thus, recalling only the names of the toys prompted children to think about categorical relations, but recalling the objects with their locations cued them to think about the spatial relations among the objects.

These results are particularly relevant to cartographic education because they show that 10- and 12-year-olds are clearly capable of organizing information spatially, but that they are most likely to do so when their attention is focused specifically on locations. This suggests that if a teacher asks students *where* coal is produced in the United States, 10- and 12-year-olds are likely to rely on the spatial relations among coal-producing states to retrieve this information. If, on the other hand, a teacher poses the question of *which* states produce coal in the United States, children may fail to use their knowledge of the spatial relations among states to retrieve this information.

#### HIERARCHICAL ORGANIZATION IN SPATIAL COMMUNICATION

The ability to communicate information about locations also plays a major role in classroom learning situations and in everyday social interaction. One issue is whether young children are capable of communicating information about locations in a spatially organized fashion. Plumert, Pick, Marks, Kintsch, and Wegesin (in press) investigated this question by comparing the organization of children's searches for hidden objects with the organization of the directions they gave to another person for finding those same objects. Six-year-olds helped an experimenter hide nine small tokens along a random route through the three levels of their home. After all the pieces were hidden, half of the children were asked to go find them all again and half were instructed to tell an adult experimenter how to go find those pieces. Of particular interest was whether children searched for the objects and described the locations in an order that reflected the floor organization of their home. Comparisons of children's searches and directions revealed that the order in which 6-year-olds searched for objects was far more organized than the order in which they told someone else to retrieve those same objects. The dissociation between their ability to carry out organized searches and to give organized directions suggests that 6-year-olds are adept at using the structure of the house to guide their movements, but have not developed strategies for accessing their spatial knowledge in an organized fashion. In fact, a second experiment revealed that 6-year-olds only produced organized directions if prompted by their

listener to tell her the next closest place to go each time they finished describing a location. The fact that 6-year-olds relied on the floor organization of their home to determine which locations were closest to one another is consistent with the research reported earlier showing that 5- and 6-year-olds' distance judgments are influenced by spatial subdivisions. However, it again suggests that younger children have difficulty accessing their spatial knowledge in an organized fashion without specific prompts to focus on the spatial relations among locations.

One implication of these findings is that although younger children have the knowledge necessary to convey spatial information in an organized fashion, teachers may need to provide explicit organizational frameworks to help children systematically access this knowledge. For example, when asked to recall the names of states, children may need prompts to start on one coast of the U.S. and work systematically toward the other coast. In addition, drawing parallels between the spatial groupings present in children's natural environments such as schools and those represented on maps of larger spaces may help children understand spatial relations that are not directly experienced. These suggestions are in keeping with recent theoretical discussions within the field of developmental psychology that emphasize the importance of the more experienced adult in structuring cognitive tasks for children to help bridge familiar and unfamiliar information (Rogoff 1985; Rogoff & Lave 1984).

The order in which children and adults convey the spatial information needed to find an individual location can also inform us about how they organize and understand spatial relations. For example, one might describe the location of an object in a multi-level space such as a home by first referring to the floor, then the room, then a large landmark within the room, and finally the landmark with which the object is located (*the keys are upstairs in my room next to the bed on the nightstand*). The previously mentioned study by Plumert et al. (in press) also showed that both adults and 6-year-old children organized their directions for finding a hidden object by referring to units of spatial information in an order of decreasing size. This suggests that even young children have some understanding of the hierarchical spatial relations among locations.

Plumert and Carswell (1992) have further investigated the hierarchical organization of information in spatial descriptions by examining the order in which adults convey spatial information, and how quickly they comprehend organized and nonorganized descriptions of location. In the first experiment, adults hid several objects in different places around their house and then recalled as much information about where each object was located that they could remember. Analyses of the order in which they produced information about each location revealed that a majority of their descriptions conformed to a hierarchically organized structure. A second experiment extended these findings by showing that adults comprehend hierarchically organized spatial descriptions more quickly than nonhierarchically organized descriptions.

The fact that both production and comprehension of spatial discourse are tied to hierarchical structures has implications for how the mind forms spatial connections, and how such links influence how we store and access our spatial knowledge. This suggests that how teachers verbally present geographic information may well influence how easily children comprehend the material. For example, the statement, *Iowa City is located in the Midwest region of the United States and is a city in the state of Iowa* is not as easily understood as the statement, *Iowa City is a city in the state of Iowa that is located in the Midwest region of the United States*. In short, when information is presented in a disorganized fashion, children may end up

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spending cognitive resources on restructuring the information, or may miss some pieces of information entirely.

## CONCLUSION

The studies reviewed here paint a rather compelling picture of how children and adults organize spatial information. One advantage of using a system of nested spatial relations to organize knowledge of locations is that it serves to simplify spatial information. By chunking locations into spatial regions, one can think about individual locations in reference to a more general set of locations rather than as completely unique pieces of spatial information. This allows us to act and think adaptively because we do not have to know the exact location of an object or a place in order to locate it effectively. For example, I may not know exactly where a particular shop is, but I know I will bump into it if I travel through a certain section of town or along a particular street. Another advantage of such a system of spatial organization is that it supports spatial inferences. Therefore, if I know that Iowa City is in Iowa, and I know that Iowa is part of the Midwest, then I can also infer that Iowa City is a city in the Midwest. Obviously, the ability to make these kinds of spatial inferences is fundamental to our everyday functioning.

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What implications might the research reviewed here have for geographic education? First, it is clear that spatial clustering and hierarchical organization of spatial information are powerful tools for remembering and reasoning about locations. Therefore, educators may be able to use children's early understanding of spatial clustering as a basis for teaching them about regional geography. In particular, children may be more likely to remember which locations are near one another if the learning process emphasizes how locations are grouped into spatial regions. Furthermore, pointing out cases in which there are overlapping spatial, categorical, and even temporal relations among locations may serve as an even stronger and more meaningful organizational framework for children. For example, New England states are related not only through spatial proximity, but also through features based on perceptual appearance and temporal events such as similar terrain and participation in the Civil War, respectively. Although little research exists on the problem, multiple sources of information about locations may be more consistent with children's everyday experiences because objects of the same class are often found in the same location. For example, kitchens usually contain locations for canned goods, pots and pans, and glassware.

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Second, the developmental changes that occur with respect to children's ability to systematically recall locations suggest that educators need to provide young children with more concrete ways of thinking about locations; in other words, perhaps incorporating knowledge with activity. For example, young children might find it more meaningful to physically walk to locations represented on a large map on the floor than to look at locations on a small upright map. By doing so, educators can use familiar experiences as a bridge for introducing more abstract and less familiar information.

In conclusion, these ideas may provide a basis for further collaboration between those in the field of geographic education and psychologists studying children's spatial cognitive development. Many questions about the relations between children's spatial cognitive development and their understanding of geography remain unanswered, however. We do not know, for example, how children integrate their knowledge of spatial clustering processes and hierarchical organization with their understanding of metric representations of spatial information. Cross-disciplinary research in this area offers a key to understanding not only how to edu-

cate children about geography, but also to unravelling mysteries about how children's spatial knowledge develops.

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#### RESUMEN

Uno de los muchos retos del sistema educativo moderno es el de proveer a los niños con un mejor entendimiento de la geografía. Cada vez más los cartógrafos y educadores se inclinan en conseguir información de los psicólogos sobre cómo es el desarrollo espacial cognitivo, la habilidad para entender y aprender sobre las relaciones espaciales en los mapas. Una parte muy importante del proceso de aprendizaje es la habilidad de organizar localidades con alguna estructura especial. Recientemente, el papel que la organización jerárquica juega en recordar y razonar localidades ha recibido gran atención en el campo de la psicología cognitiva. Estudios han demostrado que tanto los niños como los adultos tienden a organizar las localidades por regiones con niveles concentrados de detalles. Por ejemplo, el lugar del cepillo de dientes puede recordarse como en el segundo compartimento en el gabinete del baño de arriba, o la localidad de Iowa City puede ser en el estado de Iowa, en la región medio-oeste de los Estados Unidos. Sin embargo, hay limitaciones en la habilidad de los niños para hacer estructuras espaciales jerárquicas, esto tiene importantes implicaciones para la educación cartográfica. Como resultando, los niños más jóvenes pueden requerir más ayudas visuales y estructuras organizacionales explícitas cuando aprenden y comunican información sobre localidades. Las ideas y sugerencias presentadas aquí sobre la relación entre el desarrollo espacial cognitivo y su entendimiento de la geografía, tiene el objetivo de fomentar más colaboración entre los cartógrafos y psicólogos. □