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Understanding and nurturing spatial literacy

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Abstract

This paper focuses on the character, nature, and development of spatial literacy. We explore a series of questions that frame the range of knowledges and skills that encompass this form of literacy, including how spatial literacy can be characterized across a continuum of expertise; how expertise in spatial thinking and reasoning develops; how spatial literacy may be measured and evaluated; and how spatial literacy can be nurtured in society, in our research, and through teaching. By focusing on the necessary educational foundations or anchors required for spatial literacy, specifically ways in which geography and other science educators at all education levels can explicitly teach spatial concepts, the use of spatial representations, and processes of spatial reasoning, we hope to help set an agenda for future work.

Key words: Spatial literacy; spatial thinking; geospatial technology competency model; spatial practices;

1. Introduction

The purpose of this paper is to explore two related ideas: Spatial literacy is a fundamental form of literacy and yet we know almost nothing empirically about its character, nature, and development. First, we discuss spatial literacy and its importance, briefly making the case that it is significant to a wide range of disciplines and careers, not only to geospatial specialists. Then we offer a framework and call for the kinds of empirical research and deep reflection that is needed to truly support and build spatially literate societies throughout the world.

2. The Case for Spatial Literacy

There is growing recognition that spatial literacy is as important as mathematical literacy (numeracy) and classic literacy—the ability to read and write. The U.S. National Academy of Sciences found that spatial thinking, a key component of spatial literacy, "…is at the heart of many great discoveries in science, that it underpins many of the activities of the modern workforce, and that it pervades the everyday activities of modern life" [1]. Spatial literacy is a component of many professions and careers, ranging from architecture and engineering, to air traffic control, medicine and the arts. To geographers and other scholars engaged in "the spatial turn," being able to think in, with, and through space, that is, to be spatially proficient, is increasingly valuable and generative [2, 3, 4]. In many instances the burgeoning

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interest has been sparked by an understanding of the role that spatial literacy plays in implementation of geospatial technologies such as geographic information systems (GIS), remote sensing, and global positioning systems (GPS). These technologies are fundamentally changing how we see the world and interact with it. Considering these trends, to the general public, spatial literacy may be a new educational essential--an addition to the traditional three "Rs"—reading, writing, and 'rithmatic—[5]. Although definitions of spatial literacy vary, the most well-known and influential identifies it as the ability of an individual to, "…capture and communicate knowledge in the form of a map, understand and recognize the world as viewed from above, recognize and interpret patterns, know that geography is more than just a list of places on the Earth's surface, see the value of geography as a basis for organizing and discovering information, and comprehend such basic concepts as scale and spatial resolution" [5].

The Geospatial Competency Model developed by the United States Department of Labor [6] represents geospatial competence (which we feel is analogous to spatial literacy) as a pyramid with nine layered components or tiers. In the level associated with academic competencies (the knowledge, skills, and perspectives learned primarily through formal education), the geospatially competent individual is expected to master subject-specific knowledge of geography as well as skills in using GIS, cartography, field research methods, and spatial statistics. In addition to knowledge and skills, the model suggests the acquisition of three essential geographic perspectives. The first of these perspectives is spatial thinking, described as the disposition and ability to "identify, explain, and find meaning in spatial patterns and relationships such as site conditions, how places are similar and different, the influence of a land feature on its neighbors, the nature of transitions between places, how places are linked at local, regional, and/or global scales." This maps well to Goodchild's description of spatial literacy.

As location matters more and more with improvements in location-based devices and services, spatial literacy is becoming tightly linked with citizenship. The geospatially-aided citizen is a growing tool for positive and productive engagement with improving and managing society. Social media with a spatial component is becoming commonplace. Citizens are now both the producers and consumers of geographic information [7]. Individuals voluntarily provide data to GIS databases that then can be used to support public decision making. Participatory GIS is playing a key role in providing time-critical data for public safety. A statewide effort in California to map roadkill using citizen observers is an example of this growing engagement (http://www.wildlifecrossing.net/california/). Information provided by individuals is uploaded to a database; an application then populates a map with dots representing the kills. A smartphone app is in development. Citizen observers have contributed to developing a broad understanding of critical environmental issues during the Deepwater Horizon Gulf oil spill, locating oil seepage along the bayous of southern Louisiana, and in combating wildfires across the United States, particularly in California and Colorado. Further, public attention and excitement has been captured by online maps such as Bing Maps, Google Earth and Global Genie (http://web.mit.edu/~jmcmicha/www/globegenie/), and by location-based systems that use geographic information to help people undertake spatial activities like find nearby restaurants (OpenTable and OpenRice) or meet with friends at a specific place (Foursquare and Facebook Places). This has inspired new enthusiasm for maps as a form of entertainment [8] and awareness of spatial literacy.

Even more compelling an argument for attention to spatial literacy is the emerging understanding of the gate keeping role that it plays in achievement and academic success in sciences like geography, technology, engineering and mathematics (characterized as STEM in the United States). Recent research by teams of learning scientists confirms that spatial ability, measured by concrete and abstract two-dimensional and three-dimensional visualization and reasoning tasks, is a significant factor in STEM subject achievement [9, 10]. For many concerned with widening access to the sciences, these findings are significant, especially since it is confirmed that sex plays a role in some spatial abilities and thus, spatial literacy [11]. Although women are more engaged in STEM fields now than in the past, they are still underrepresented in many disciplines, particularly those which are mathematics-intensive, attributable in part to variations in spatial abilities [12]. This has led to calls for explicit attention to improving spatial

skills in girls and women, including explaining that spatial skills are not innate but can be developed; encouraging young people to engage in activities that use spatial skills; and using hand held models and representations to assist in visualization tasks [13].

Increasingly calls for spatial literacy have been featured in education efforts in the UK, United States, and Australia. The US National Geography Standards feature spatial literacy through "the spatial perspective," one of geography's two key perspectives, defining it as "The essential issue of 'whereness'—embodied in specific questions such as, Where is it? Why is it there?" [14]. The National Geographic Society in association with the National Council for Geographic Education, the Association of American Geographers, and the American Geographical Society is leading a community-wide effort to engage in a set of research-synthesis and dissemination activities to guide the planning, implementation, and scale-up efforts to improve geography education over the next decade. The reports, targeting policy makers, stakeholders, and educators, are being developed by expert committees in three areas: assessment; professional development and instructional materials; and educational research. The context for the project is the growing national need for a spatially literate population. The case for spatial literacy is simple: it is a powerful and compelling way of seeing the world used in a range of contexts in every day life as well as in academic pursuits and the workplace

3. Defining Spatial Literacy

Spatial literacy is thus important in the workplace, for academic achievement, and broadly to modern society for the opportunities it affords individuals and societies. For the purpose of this paper and as a jumping off point, we conceptualize spatial literacy following Goodchild [5] as a broad range of perspectives, knowledge, skills, and habits of mind, or dispositions. The application of these can be characterized as spatial thinking; spatial reasoning is a sub-skill of spatial thinking, distinguished as the specific processes applied while thinking spatially to solve problems and make decisions. Spatial literacy, we presume, is the outcome of spatial thinking and spatial reasoning: if one can think and reason in, with, and about space, one can be considered spatially literate. But what does this really mean?

The NRC study, *Learning to Think Spatially* [1], proposed a three-part framework to consider the components of spatial thinking: 1) concepts of space; 2) tools of representation; and 3) processes of reasoning. To think spatially, it was posited, one must develop a knowledge of spatial concepts such as direction, distance, and spatial association; attain skills in constructing and interpreting graphic representations such as diagrams, maps, and graphs; and acquire and practice the cognitive strategies (or habits of mind) that facilitate problem-solving and decision-making in spatial contexts. Spatial thinking, then, was seen as an amalgam of concepts, skills, and cognitive approaches that allow individuals to use space to model the world, real and imagined, in valuable and productive ways. Spatial thinking defined in this way, as a functioning process, facilitates the development of spatial literacy.

A typology of spatial thinking, derived from the context in which the spatial thinking takes place, has proven useful when thinking about opportunities to develop spatial literacy. Walking to school, taking a shortcut to avoid a traffic jam, playing a team sport such as football, or packing a suitcase—actions that are performed in space—all require spatial thinking in a real-world or environmental context. The second type of spatial thinking, thinking about space, is typically employed when individuals learn factual information, organized as facts and generalizations, about how the world works. The third type of spatial thinking, thinking with space, is more abstract yet a powerful tool. Spatializing non-spatial data or using space as an organizing framework to conceptualize problems and make decisions is an effective cognitive strategy used frequently in problem solving.

But these ideas are largely preliminary. We really know very little about the exact nature of spatial literacy. In the next section of this paper we outline the grand challenge.

4. The Grand Challenge

In 1994, Roger Downs wrote the seminal paper on geography education Being and Becoming a Geographer. In it he called on geographers to produce empirical research to identify and inform key decisions related to the content and sequencing of geography instruction. "Further," he wrote, "I would argue that we do not have satisfying answers to questions that are fundamental to understanding the nature of geography, geographers, and geographic competence" [15]. This observation is equally true in the case of spatial literacy. While spatial literacy is certainly related to geographic competence, it is not directly equivalent and is applicable across many domains of science and engineering. Nonetheless, the series of questions Downs posed in this article as a research agenda for geography education serve well as a framework for research and consideration in the realm of spatial literacy.

Following Downs we propose that what is needed for us to move forward is a research agenda focused first on a careful and empirically based description of spatial literacy across many domains. We specify "across domains" since we can assume that spatial literacy, like other forms of literacy, will be domain specific; that to be a spatially literate geographer will be different from, for example, a spatially literate geoscientist [16]. However, this in and of itself is a topic for further research. The initial research, conducted using a range of methods from ethnography to controlled experiments, might focus on the character, nature, and development of spatial literacy: What are the characteristics of spatial literacy? What are the origins of spatial literacy? What are the components required for spatial literacy? Part of this exercise would be to characterize spatial literacy across a continuum of expertise, from the beginner or "novice" to the experienced professional or "expert."

Goodchild describes things a spatially literate individual does; the Geospatial Competency Model breaks expertise down into discrete components—but how do all these pieces characterize spatial literacy? What does it mean, in concrete knowledge, behavior, and action, to be spatially literate? Interestingly then, where do these characteristics come from? Downs refers to Sauer's metaphor the "geographic bent" to discuss interest in or proclivity toward seeing the world spatially, through the "morphological eye" [17] Empirically then there is a need to analyze and understand how one becomes "spatially bent." What formative experiences, what aptitudes and educational settings, what sociocultural contexts support the origins of spatial literacy? An interesting way to proceed in this line of inquiry might be to look at life lists of spatially literate people. The idea of a life list, originally associated with inventorying the sightings of species of birds, has become more commonly defined as establishing goals or lists of things one wishes to do, see, or experience in life. Salter and Meserve [18] suggest a typology of a life list for geographers, realms of activity that they consider fundamental to the development and interests of a geographer, including travel, observation, exploration, the use of maps, speculation, and participation. What would the typology of spatial literacy look like as derived from the life lists of spatially literate people?

The second part of the research agenda should focus on how expertise in spatial thinking and reasoning develops. This concern compels researchers, especially those with special interests in spatial literacy, to understand how to educate a spatially literate populace. Of course, such research will need to take into account the levels of expertise to be acquired and thus, to identify benchmarks of spatial literacy. These benchmarks could be statements of the knowledge(s), skills, and dispositions that characterize the progression from beginner (novice) to experienced spatial literate (expert). Research on whether there are anchors of spatial learning, defined as key knowledge and experiences that provide the foundations for further development of literacy, could be part of such a research agenda.

However we proceed, we need to build from what is already known about the development of spatial thinking and reasoning, therefore, the foundations of spatial literacy. First, we already have a firm understanding that the characteristics of individuals matter. Research in spatial thinking and reasoning conducted by cognitive scientists, psychologists, and geographers confirms that spatial skills develop uniquely in individuals. Sex, experience, age, culture, and education all play a role in spatial literacy. Second, context matters. Research has also confirmed that expertise develops in specific contexts (including disciplinary contexts) and that its transfer from one area to another is not automatic, as we

indicated in our previous call for research in certain domains. A habit of mind, concept, or skill learned in science class may not be used automatically in an equally appropriate geography application unless explicit prompts are given. Third, scale matters. It is important to acknowledge the role that scale plays in spatial thinking and spatial literacy. There appear to be differences between large-scale and small-scale spatial thinking just as there are differences in thinking in, about, and with space [19]. There are also differences between thinking in space (wayfinding) versus about and with space. Fourth, task analysis and alignment matters. It is essential to analyze spatial tasks related to spatial literacy and activities using the typology of the types of spatial thinking (thinking in space, about space, or with space) for two reasons: to make clear the kinds of experiences that will promote varying skills and to understand the roles that individual differences play in spatial thinking. Finally, teaching matters. The findings are that spatial thinking can, and should, be learned by all, thus laying the foundation for spatial literacy [1, 20].

As part of our proposed research agenda, there is a need for attention to the ways that spatial literacy can be measured and evaluated. This is, of course, part of the overall mission to understand the characteristics and nature of spatial thinking, reasoning, and how it is nurtured and developed. Once a clear description of the components and competencies referred to above can be developed, powerful, reliable, authentic, and valid assessment instruments can be devised. These can serve as useful tools for research, benchmarking spatial literacy, evaluating the importance of proposed anchors, and in measuring progress along a continuum from an individual developing spatial literate to a fully competent and expert spatial literate.

5. Conclusion

By focusing on the necessary foundations required for spatial literacy, specifically ways in which geography and other science educators at all education levels can explicitly teach and nurture spatial concepts, the use of spatial representations, and processes of spatial reasoning to students, we hope to have set an agenda for future work. The ongoing concern for this audience and other readers of this paper is how to uncover, explicate, develop and move forward the cause of spatial literacy in education, in the workplace, and in society. We, as a collective, must begin a discussion on how to implement the ideas presented and devise ways we can work collaboratively with geospatial professionals, geographers, learning scientists, and others who share our vision of a spatially literate society. We do not have the answers or even many tentative hypotheses. We do have a range of recommendations for how to move forward to establish the foundations of spatial literary based on our individual areas of expertise—as geographers with deep interests in learning and spatial practice.

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