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What do we mean by "spatial literacy" in a GIS context?

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1. Introduction

The context for this paper lies within the Spatial Literacy in Teaching (SPLINT) initiative, a HEFCE funded Centre for Excellence in Teaching and Learning (CETL) led by the University of Leicester working in conjunction with the University of Nottingham and University College London. The focus of SPLINT is on the pedagogy[1] of geospatial technologies, the pedagogy of taught postgraduates and the enhancement of spatial literacy. Clearly, in order to enhance spatial literacy we must understand the parameters of the concept, yet despite a considerable body of research there is considerable ambiguity regarding the term. This is partly the case since spatial thinking is embodied in many disciplines, for example psychology, geology and geography. There remains a need to frame spatial literacy *as related to GIS*, that draws on the literature from multiple disciplines and synthesises and extends where appropriate those aspects of the term most appropriate to the practice of GIS. With this in mind, this paper represents a synthesis of research on spatial cognition, and more specifically on spatial abilities, in order to define spatial literacy.

Although the term "spatial" is rarely defined (Foreman and Gillet, 1997, p. 3), it is used to form multiple phrases: spatial cognition, spatial knowledge, spatial behaviour, spatial ability, spatial task, spatial skill, and so on. Despite this lack of clarity regarding the term "spatial", three statements are widely accepted: (1) there is ample evidence that "spatial" knowledge is a separate component of human intelligence, distinct from verbal and analytic aspects; (2) the "spatial factor" is not a unidimensional concept because different spatial abilities have been identified (Morrow and Ratcliff, 1988, p. 5); and (3) experience is important for acquiring spatial knowledge (Foreman and Gillet, 1997, p. 6; Golledge, *et al*, 1995). From a pedagogical point of view, these statements imply that some "spatial" abilities can be taught and learned; consequently, the term "spatial literacy" emerges as a generality. The multiple dimensionality of the term in a GIS context however requires further pursuit.

2. What do we know, from psychological approaches, about spatial abilities?

In psychological research (regarding spatial cognition) there are different research traditions, methods, objectives and conceptualizations (Cornoldi and Vecchi, 2003, p. 9). In this paper, four traditions have been identified and they are as follows: developmental, psychometric, information-processing and clinical neuropsychology (see Sternberg, 2003, pp. 484-522).

Psychometric approaches have gathered more evidence than any other approaches. Within these

[1] Pedagogy is the act and discourse of teaching, It is what one needs to know, and the skills one needs to command, in order to make and justify the many different kinds of decisions of which teaching is constituted. Pedagogy dictates attention to the domain of ideas and values, and to ways of organising and relating them (Alexander, 2004).

approaches, it is important to notice that John B. Carroll, following Lohman (1987), developed an influential hierarchical model for intelligence that recognised the importance of cognitive spatial abilities (Carroll, 1993). Carroll's framework is often used in the studies of imagery[2], which is one of the most active and respected areas of current cognitive psychology research (Baddeley and Andrade, 2000). Our research takes into account Carroll's strong legacy, Lohman's more recent report (Lohman, 2000) and above all the interesting synthesis of visuo-spatial abilities made by Cornoldi and Vecchi (2003, p. 16).

3. What do we know about the relationships between geography and spatial abilities?

In geography, Reginald Golledge has been an influential scholar in the arena of spatial cognition, particularly in regard to the acquisition of spatial knowledge (see Golledge, *et al*., 1995; Golledge and Stimson, 1997). Although Golledge used psychometric tests and took into account the approaches of psychometric studies, perhaps surprisingly he failed to consider Carroll's framework for spatial abilities in an explicit fashion despite its apparent relevance to many tasks in geography and indeed GIS. Rather, Golledge's work pivots around the early synthesis of Lohman (1979). Most recently, the US National Research Council (NRC) published a book called *Learning to Think Spatially* (NRC, 2006), which offers a broad framework about spatial thinking, which is shown in a brief presentation in Table 1. This new framework is being compared with various from geosciences (e.g. Ishikawa and Kastens, 2005), psychology (e.g. Cornoldi and Vecchi 2003) and geography (e.g. Golledge & Stimson, 1997). The result of these comparisons will inform our cross-disciplinary view of the diverse axes of spatial thinking, leading to the emergence of what we term an embryonic "mega-framework" of spatial literacy.

Types of representations, transformations and reasoning	Encoding processes
IA. Representations: *The Properties of Entities*	1a. Distinguishing figures from ground; 1b. Distinguishing (level II); 2. Recognizing patterns; both outline shapes and internal configurations; 3. Evaluation size; 4. Discerning texture; 5. Recognizing colour; 6.Other attributes.
IB. Representations: *The Relations Between Static Entities*	1. Determining orientation; 2. Determining location; 3. Assessing distance; 4. Comparing size; 5. Comparing colour; 6. Comparing shape; 7. Comparing texture; 8. Comparing location; 9. Comparing direction; 10. Comparing other attributes.
IC. Representations: *The Relations Between Dynamic Entities*	1. Direction of movement; 2. Manner of motion; 3. Speed or acceleration; 4. Intersection or collision.
II. Transformations *of Representations of Entities*	1. Changing perspective; 2. Changing orientation; 3. Transforming; 4. Changing size shapes; 5. Moving wholes; 6. Reconfiguring parts; 7. Zooming in or out; 8. Enacting; 9. Planning.
III. The Processes of Complex Spatial Reasoning	Several representations, several comparisons and multiple transformations. 1. Role of Distortions in Spatial Thinking; 2. Role of Abstract Spatial Thinking; 3. Role of External Spatial Representations in Spatial Thinking; 4. Effective External Representations; 5. Effective External Representations; 6. Role of Expertise in Spatial Thinking.

[2] A mental process with output in an internal visuo-spatial representation (Cornoldi and Vecchi, 2003, p. 5)

Table 1. Spatial thinking rests on the interplay between mental representations (that capture spatial features of the world) and the transformations (that can be applied to those representations) (NRC, 2006, pp. 41-47)

4. How do common GIS tasks map to aspects of spatial ability identified in the joint literatures?
We can see from discussions in sections 2 & 3 that there are different frameworks for spatial thinking (from psychology and from geosciences). In other words, as Black (2005) points out, there is no consensus concerning names and descriptions of spatial ability types. With few exceptions, there has also been little recent merging of the findings between the disciplines of geography and psychology.

Of particular value to our context, Albert & Golledge (1999) have undertaken early studies confirming that spatial cognitive abilities play a fundamental role in the use of GIS ideas echoed within the book from NRC (2006) mentioned above. These publications suggest that furthering our understanding regarding how these abilities play out across a diverse range of GIS users may be of assistance in the design of GIS functions, and implicitly in how we teach GIS. We also see a hierarchy of abilities ranging from the low level basic navigational and recognition tasks (e.g. rotation) to the higher level abilities that encompass the synthesis of meaning and causality in spatial pattern in addition. Therefore, we suggest the possibility of building a continuum of learning in spatial knowledge. We borrow from the work of Stables and Bishop (2001) in referring to this continuum of literacy as one between "functional" (low level spatial thinking) to "critical" (high level spatial thinking).

Our research, currently on-going, seeks to map common tasks required of the GIS practitioner across multiple level factors from the multi-disciplinary literature across a broad range of axes of a "mega-framework" (which results by comparing four frameworks). While simultaneously developing a hierarchical continuum of tasks associated between "functional" to "critical" literacy. Representative GIS tasks will be drawn from the UCGIS 'Body of Knowledge 2006' (di Biase 2006) and assigned to aspects of that "mega-framework" by multiple academic practitioners of GIS. In this process, it is intended that the "mega-framework" itself will self-organise; important lower and higher level spatial abilities commonly referred to will grow and others shrink, while additional axes relating for example to aural-spatial ability or data collection may alter the "mega-framework." In this manner, spatial literacy as especially relevant to the practice of GIS will unfold for conference presentation and further debate.

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References
Albert W.S. & Golledge R.G. (1999) The Use of Spatial Cognitive Abilities in Geographical Information Systems: The Map Overlay Operation. *Transactions in GIS*, **3**(1), pp. 7-21.

Alexander, R. (2004) Still no pedagogy? Principle, pragmatism and compliance in primary education. *Cambridge Journal of Education,* **34(**1), pp. 7-33.

Baddeley, A. D. & Andrade, J. (2000) Working Memory and the Vividness of Imagery. *Journal of Experimental Psychology: General,* **129**(1), pp. 126-145.

Black, A. A. (2005) Spatial Ability and Earth Science Conceptual Understanding. *Journal of Geoscience Education,* **53**(4), pp. 402-414.

Carroll, J. B. (1993) *Human Cognitive Abilities: A Survey of Factor-Analytic Studies* (New York:

Cambridge University Press).

Cornoldi, C. & Vecchi, T. (2003) *Visuo-Spatial Working Memory and Individual Differences* (Hove, East Sussex: Psychology Press).

di Biase, D. (2006) *Body of Knowledge 2006*. University Consortium for Geographic Information Science. pp115.

Foreman, N. & Gillet, R. (1997) *A Handbook of Spatial Research Paradigms and Methodologies* (*Volume 1: Spatial Cognition in the Child and Adult)* (Hove, East Sussex: Psychology Press).

Golledge, R. G., Dougherty, V. & Bell, S (1995) Acquiring Spatial Knowledge: Survey Versus Route—Based Knowledge in Unfamiliar Environments. *Annals of the Association of American Geographers,* **85(**1), pp. 134-158.

Golledge, R. G. & Stimson, R. J. (1997) *Spatial Behavior: A Geographic Perspective* (New York: The Guilford Press).

Ishikawa, T. & Kastens, K. A. (2005) Why Some Students Have Trouble with Maps and Other Spatial Representations. *Journal of Geoscience Education,* **53(**2), pp. 184-197.

Lohman, D. F. (1979) *Spatial Ability: A Review and Reanalysis of the Correlational Literature.* (Technical Report No 8) (Stanford, CA, Stanford Univesity).

Lohman, D.F. (2000) Complex information processing and intelligence. In R.J. Sternberg (Ed.) *Handbook of Human Intelligence* (2nd ed.) (pp. 285-340). Cambridge, MA: Cambridge University Press.

Morrow, L. & Ratcliff, G. (1988) Neuropsychology of Spatial Cognition: Evidence from Cerebral Lesions. In Joan Stiles-Davis, Mark Kritchevsky and Ursula Bellugi (eds.) *Spatial Cognition (Brain Bases and Development*) (Hillsdale, New Jersey: Lawrence Erlbaum Associates), pp. 5-32.

NRC (National Research Council) (2006) *Learning to Think Spatially* (Washington, D.C.: The National Academy Press).

Stables, A. & Bishop, K. (2001) Weak and Strong Conceptions of Environmental Literacy: implications for environmental education. *Environmental Education Research,* **7(**1), pp. 89-97.

Sternberg, R. J. (2003) *Cognitive Psychology* (Belmont, CA: Wadsworth/Thomson Learning).

Biography

Benjamin Pozos-Hernandez is an educational research assistant at the Geography Department, University of Leicester. His recently submitted PhD thesis to the University of Cambridge (Faculty of Education), is entitled 'Mexico City: an environmental tour. The Development and Evaluation of a Learning Tool for Sustainable Development and Environmental Education'.