

In Search of Spatial Literacy: the Nottingham Sputnik Model

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KEYWORDS: Spatial Literacy, Spatial Skills Test, Nottingham Sputnik Model

1. Introduction

Tate et al. (2005) highlight the need to establish 'benchmark measures and diagnostic tests' of spatial literacy. This paper addresses such concerns by evaluating an existing test of spatial skills, recognising that skills and literacy may not be the same thing. It presents a new model of spatial literacy that was developed from end-user feedback. This conceptual model is then used to pinpoint the relationship between GIS and spatial literacy. The selected test is both broad enough, and designed with sufficient geographical expertise, to permit the exploration of end-user results and to support some initial steps towards providing a working definition of spatial literacy. The fallacy of confusing measuring instrument with concept is nevertheless acknowledged.

Spatial literacy is a complex issue (Hernandez et al., 2006, King, 2006). It is also something of a 'holy grail' and many have sought to define it. Goodchild (2006) exemplifies the difficulties of this challenge by defining spatial literacy in broad-brush terms as 'a set of abilities related to working and reasoning in a spatial world', a general definition at best. Albert and Golledge (1999) refer to three standard subdivisions: spatial orientation, visualization and relations. The National Research Council (2006) has recently proposed a substantial framework that encapsulates different mechanisms related to 'spatial thinking' including (i) consistent spatial thinking, (ii) being able to represent spatial concepts and (iii) possessing spatial knowledge. Thus spatial literacy remains an elusive concept: it means different things to different people and cannot be compartmentalised into a simple description. However, an agreed model for spatial literacy could be used to inform educational policy and teaching guidelines. The Association of American Geographers has responded to the need for teacher training material by developing a *Teacher's Guide to Modern Geography*. This project is funded by FIPSE (US Department of Education). The primary aim of the teacher's guide is to improve the preparation of pre-service teachers. Jongwon Lee, under the auspices of this programme has constructed a test to assess teachers' mastery of the guide's content and skills: the so-called 'spatial-skills test' (SST) (Association of American Geographers, 2007). This twenty item, standardised test measures performance on a variety of tasks based on many aspects of spatial thinking and interpretation, including orienting on a street map, comparing map information to graphic information, choosing the optimum location based on several spatial factors, imagining a slope profile based on a topographic map, correlating spatially distributed phenomena, overlaying maps, and recognising spatial data types (point, line, or polygon) based on verbal descriptions.

In this paper, we present a 'first pass' evaluation of SST. This test was evaluated from the point of view of 'testing the test'. The test was adapted so it could be delivered in a controlled environment and scored electronically. The test was digitised by using the images from the online version and using HTML and JavaScript to compute the scores and deliver the test. Impressions of the test were then gathered from students. In response to this feedback we propose a set of modifications to the initial test and options to be explored in subsequent

developments. Next, from our experiences, we present a tentative model of spatial literacy based on emergent concepts and constructs within the test. This model is then used to identify the relationship between GIS and spatial literacy.

2. Method

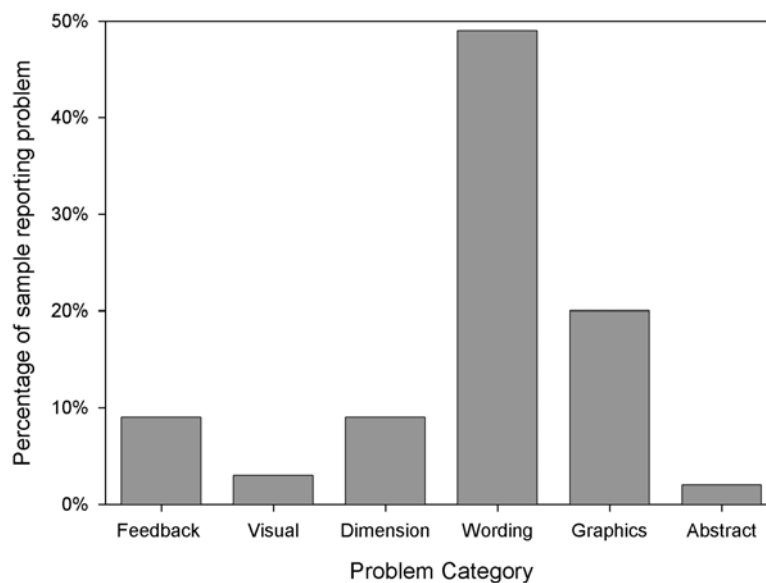
A first-year cohort of geography undergraduate students were asked to complete the test. Following the test, any criticisms students had were recorded. A completely unstructured approach was taken to elicit student opinion. Students were asked to write their criticisms down candidly. Ninety-eight students returned their opinions to the experimenters. Categories were developed in response to student feedback. The opinions were then sorted into categories. The analysis is shown in Figure 1. Criticisms are shown as proportions of the full sample size, grouped into problem categories. The problem categories were developed from the criticisms. Definitions of the problem categories are shown in Table 1. Throughout this paper, individual questions are referred to as Q1, Q2, etc.

Table 1 Definition of each problem category

Problem Category	Definition
Feedback	Immediate feedback preferred by the student
Visual	Domination of questions which test visuospatial skills
Dimension	Lack of clarity as to what skills the test is testing
Wording	Poor or ambiguous question wording
Graphics	Poor or ambiguous question graphics
Abstract	Question highly abstracted and lacking geographical context

3. Analysis

Figure 1 Number of students reporting problems in each category as a percentage of the total sample returned

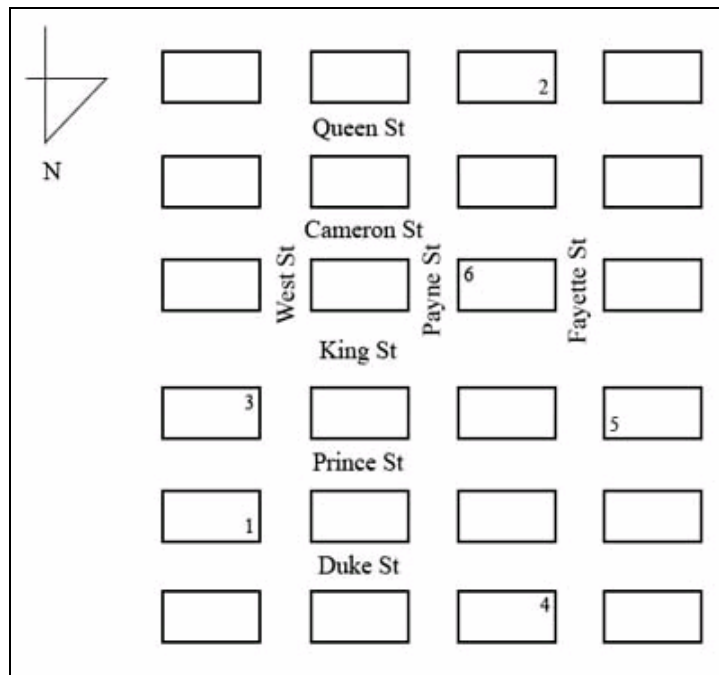


With reference to Figure 1, a larger proportion of the participants noted problems with question wording and low resolution or ambiguous graphics associated with the test. Sentence

structure and instances of contradictory wording, particularly with regard to the spatial correlation questions, confused many participants affecting their ability to answer the questions. For example, the lead in to Q10 and Q11 indicates that participants should find one positive and one negative spatial correlation. The individual questions then require participants to find two positive correlations. In Q1 and Q2, there are semantic ambiguities. Other participants remarked on low-resolution graphics preventing effective answering of questions. Many participants also wanted immediate feedback; in our implementation this was not delivered. Given the electronic delivery of the test this should pose no problem in the future. Following reporting of these problems, a logical appraisal of the test was undertaken and a set of potential modifications were developed. In developing this list it was important to consider the range of software packages which are available to assist the researcher to electronically deliver the content of tests. In this case Question Mark Perception™ (QMP) authoring software was selected as the basis for selecting potential modifications. This package allows maximum flexibility in the processing and presentation of results. Innovative interaction styles can be specified increasing the level of student engagement in a way that static HTML, or form based authoring software cannot emulate.

Substantial improvements could be made to the interactive elements of the test, increasing the clarity of the questions and addressing student concerns over the graphics and layout of the test. Additionally changes to the wording could be made where deemed unclear. Figure 2 shows the stimuli for Q1 and Q2 on the SST. In this question students are required to complete a sequence of spatial operations and report their new location on the map. A clearer, more familiar north-arrow could be used. The question involves the concept of a block, in which a block is represented by rectangles on a map. The rectangles are separated by streets. The start and end locations are represented by numbers placed in the corner of the rectangles. It is not clear whether movement in terms of blocks represents corner-corner or block-block movement and where the streets fit into the conceptual movements demanded of the question. The concept of movement by block is currently ambiguous and needs to be defined ensuring that spatial dimensions are being tested, as opposed to the chance matching of a linguistic concept. Additionally the method of interaction could be changed. Users could move an object around the grid and click enter when the object is on the correct block removing the need for finish points to be specified. This is in contrast to the drop down box provided in the original version; users could now interact directly with the material. A number of other questions could be adapted in this way (e.g. Q4, 5, 9) to reduce ambiguity and afford a more direct method of interacting with the test. Many questions used US style concepts and language. Q19 highlights another ambiguity in wording. In the original question the answer depends on the concept of a bus route. If this concept includes only the route, this can be described as a line. If the concept is expanded to include bus stops, points and lines are a more appropriate response. In the original question, both responses are available but only one is recorded as correct.

Figure 2 SST stimuli for Q1



Many students remarked on the more obvious issues with the test; layout, interaction, ambiguity. Smaller numbers of students noted more subtle problems with the test. Some parts of the test present abstract stimuli such as the shape matching and overlay questions (Q13 - 16). These questions were unpopular with students as they tended to be more difficult and more aligned with psychological notions of spatial ability, lacking the geographical context that could anchor the reasoning required in other questions. Other students noted the emphasis on visuospatial skills as opposed to knowledge of spatial concepts or linguistic spatial reasoning. Most questions in the test contain visual stimuli, on which judgements must be made. This kind of criticism moves more into the ‘what are we testing’ debate and highlights an issue with the test as it stands.

An evaluative framework with which to approach this question is the psychometric perspective, the cornerstones of which are reliability, sensitivity and validity of a test instrument (Kline, 1993, Cohen and Swerdlik, 2005, Kline, 2005). Several psychometric tests have been developed which examine very specific spatial skills. For example, mental rotation (Shepard and Metzler, 1971), perspective taking (Hegarty and Waller, 2004), attitude towards own sense of direction (Hegarty et al., 2006). These tests were all developed in the psychometric tradition: each test contains a number of items that measure a single construct or concept; mental rotation, perspective taking or attitude. These tests have the benefit of higher reliability due to many similar items that are designed to test the same spatial skill. Statistical techniques are then used to assess the test items, weeding out weaker questions and ensuring that all questions are measuring what they should be. In this way empirically derived measures of the reliability, sensitivity and validity of the test can be formally established and published.

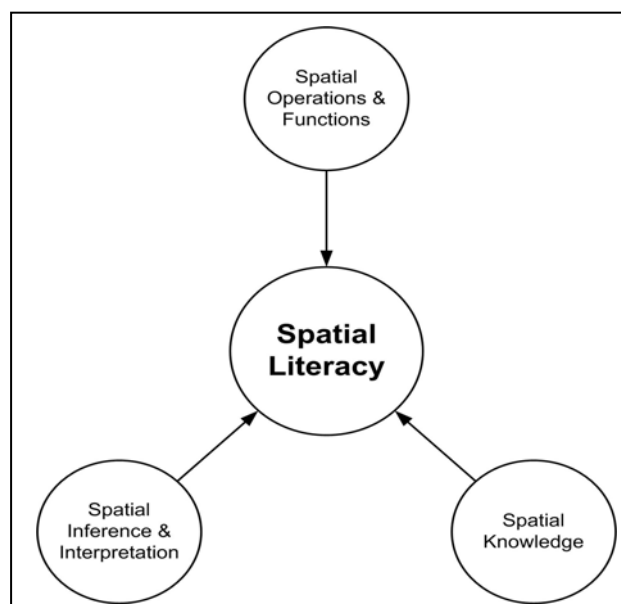
SST in its current form does not sit easily within the psychometric approach but we can base our assessment of its merits within this perspective. The test has many different kinds of item measuring many different kinds of abilities. The majority of items focus on visuospatial abilities requiring spatial operations and perspective shifts (Q6 - 9). Other parts require interpretation and inference from spatial data (Q3, 10, 11). In the final part of the test (Q17 - 20) factual, or declarative, knowledge is tested. Students are required to demonstrate knowledge about the building blocks of GIS: points, lines and polygons. This kind of

knowledge relies more on educational background rather than spatial skills per se. The small number of items testing each component of spatial literacy means that reliability may be an issue with the test. For example, a basic lack of knowledge about GIS would result in light penalties for a student answering the final questions in the test which relate to this knowledge (Q17 - 20). Many more questions deal with spatial operations and functions. A student weak in this area of spatial literacy would incur heavy penalties and perhaps this is the correct balance. It is up to the geographic community to decide what is important. Longer tests with more questions testing the same skill will give a more reliable measure of that skill. Again, given the small number of items, the sensitivity of each question requires exploration. Not unreasonably, we want our students to be spatially literate. Some spatial skills are innate: others, we hope can be developed or improved with training or education. To know whether such outcomes are possible and if we are achieving or failing in our expectations will require a trusted diagnostic testing instrument. Spatial cognition, experience, ability or knowledge in combination or individually, may all be under the microscope at any given point during the SST. However what do incorrect answers to specific questions mean in terms of spatial literacy? In the following section, we propose a conceptual model of spatial literacy based on fundamental building blocks around which subsequent developments can be proposed.

4. The Bigger Picture

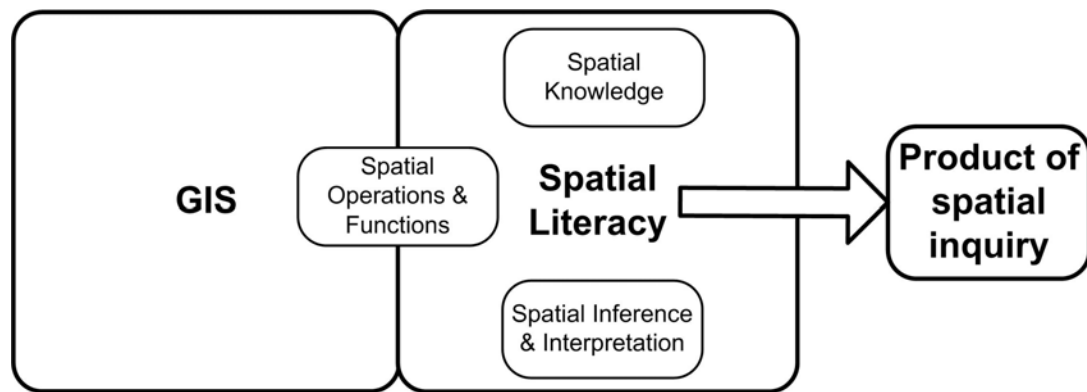
The initial suggested changes to the test will provide a sharper tool upon which to base future research into the validity and reliability of that instrument and permit further inferences to be made about spatial literacy. However, in broader terms, our experiences suggest a more radical overhaul of the test and to support such developments we propose the conceptual model depicted in Figure 3. This is the Nottingham Sputnik Model of Spatial Literacy (NSM). Spatial literacy is shown as a latent concept. Three spokes of interest are included: spatial knowledge comprises declarative knowledge or geographical facts. Spatial inference is the ability to interpret and make inferences from spatial data. Finally spatial operations and function can be thought of as the cognitive part of spatial literacy; the ability to manipulate and transform space in the mind. Each group of distinct skills and knowledge are tested in the test hence their inclusion in our conceptual model. Taken together we propose a tentative definition. Spatial literacy is composed of the three spokes which when converged form the ‘raw ability’ that allows the individual to manage and interpret geospatial data and materials.

Figure 3 Nottingham Sputnik Model



There remains a need to frame spatial literacy as related to GIS with particular reference to tertiary education. The proposed model is flexible enough to be able to handle this question without adding undue complexity to its structure. Figure 4 shows how GIS can be seamlessly positioned within the model. GIS feeds into the ‘spatial operations and functions’ part of the model. GIS software routinely handles many spatial operations on large datasets or performs complex queries that would simply place too much burden on human memory or cognition to be implemented in any other way. Spatial literacy is required for the correct selection of operations and their subsequent interpretation. Our conceptual model would suggest that the quality of output, be that in a student assessment or real-world application, would depend on the degree of spatial literacy possessed by an end-user.

Figure 4 Extended Sputnik Model



5. Conclusions

New tools and testing instruments should always be evaluated and the results of that process acted upon. It is easy to fall into the trap of simply reproducing the paper version of any test online without considering the increased flexibility that different interaction styles and layouts can give. Delivering a test electronically has many benefits. Very large sample sizes can be tested at the same time or in different locations, limited only by the availability of computers or internet connections. Automated delivery of the test can be highly controlled; individual questions can have time limits allocated to them or extra time can be provided. Machines can be locked down in ‘kiosk mode’ to prevent other programmes being run and referred to. For the researcher, the benefit of immediate access to captured data including automated processing, storage and analysis while avoiding drudgery of error-prone data entry by hand is enormous. Students can benefit from instant feedback if appropriate and a wide range of dynamic interaction styles can be used generally eliciting positive user response. We have described certain changes that should be made: it is nevertheless difficult to keep abreast of rapid developments in smarter software.

Returning to the psychometric perspective and SST. In its current form, the test has high face validity; it appears to be measuring something to do with geographical skills. This is to be expected since the test was developed by geographers. However, the construct validity of the test remains a matter of concern. Construct validity refers to the alignment of that test with some theoretical framework or concept. We have proposed spatial literacy as the latent construct, embedded within the test, itself composed of different skill and knowledge spokes. Using and understanding spatial skills testing could shed further light on the extent to which these separate components interact.

Without a great deal of further work, we may never be sure quite where or when or indeed what skills are being used. NSM integrates different aspects of SST while handling the conceptual structure of spatial literacy. The models listed in the introduction (Albert and

Golledge, 1999, Goodchild, 2006, National Research Council, 2006) all describe diverse aspects of spatial literacy. The concepts proposed in these earlier publications can be related to NSM: such models both (i) dovetail with its structure and (ii) are described by it. This paper offers a fresh perspective that is presented for discussion. It is believed that spatial literacy, or at the very least its covariates, reside somewhere in the SST. Having sharpened the instrument and developed the conceptual model, we now set to explore matters further.

Acknowledgements

The authors would like to thank Michael Solem, Director of Educational Affairs at the Association of American Geographers, and the Association of American Geographers as a whole for permission to use their test materials.

Special thanks must also go to the University of Nottingham students who participated in our experiment. Their time and effort is much appreciated.

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Biography

Jim Nixon is a research student examining human factors issues surrounding the perception and communication of different geospatial representations over mobile communications. Jim holds an undergraduate degree in psychology and a masters degree in human factors. He is a graduate member of both the Ergonomics Society and the British Psychological Society and is working towards professional registration.