Chapter 2
Location across Disciplines: Reflections on the CSISS Experience

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2.1 Introduction

The importance of geographical location as a mediator of societal and environmental processes has been acknowledged for several centuries. Nonetheless, it is only recently that scholars have had access to powerful computational and modelling tools to account for the role of location in explaining processes and patterns of change. Related to this new reality, this chapter has two objectives. First, it seeks to document the expansion of locational perspectives across disciplines based, in part, on programmes of the Center for Spatially Integrated Social Science (CSISS)[1] in the United States. The second objective draws on the experiences of CSISS programmes for nurturing an understanding of core spatial concepts in conjunction with the exposure of students to spatial analytic tools. The chapter identifies fundamental spatial concepts and their value to scientific reasoning and to the development of sound policy applications in business and civic life.

2.2 Extending Locational Perspectives across Disciplines – The Experience of CSISS

CSISS was founded in 1999 to develop research infrastructure in the social and behavioural sciences (Goodchild, et al., 2000). Since then, CSISS has facilitated the sharing of ideas and methods among researchers in the social and behavioural sciences, promoting the national dissemination of spatial analytic tools, including

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[1] CSISS was funded by the National Science Foundation (NSF BCS 9978058), hosted by the University of California Santa Barbara and directed by Michael Goodchild (see www.csiss.org). Its week-long workshops were offered through UCSB (2000–2004) and Ohio State University (2001–2003), the University of California Los Angeles (2000), the University of Washington (2000) and Pennsylvania State University (2003).

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cartographic visualisation, geographic information systems (GIS), pattern recognition, spatially sensitive statistical analysis and place-based search methodologies. Through workshops, web technologies and publication programmes, CSISS enhanced accessibility to these tools and ways of thinking and fostered opportunities for scholars to master spatial methodologies.

The establishment of CSISS coincided with a period in the history of the social sciences when scholars from a wide range of disciplines were beginning to acknowledge the importance of space and time for providing context to observations. Space is increasingly seen as a means for organising knowledge, a basis for addressing and modelling fundamental social concepts (such as interaction, separation and connectivity) and as an element in evolving theory. Although objective measurement of underlying trends in scholarship is difficult, CSISS has collected statistics on the prevalence of spatial thinking in the literature, interest in its training workshops and activity on its website. All of these support the assertion that interest in space has grown and that funding initiatives from governments and foundations have had a significant impact on the ability of social scientists to make use of spatial thinking, tools and data (Goodchild 2004).

2.2.1 Modelling a Programme for National Dissemination

Although the move to incorporate spatial methodologies had already begun prior to the founding of CSISS, advocates for spatial thinking in most social sciences were small in number. There was little evidence of spatially informed instruction at undergraduate levels and, with the exception of a few disciplines (e.g. archaeology, geography and planning), graduate programmes had not integrated spatial analysis into their training. Faced with the question of how best to present the case for spatial analysis in the social sciences, CSISS developed an operational strategy to advance spatial methods to a more central position across various social science communities. Figure 2.1 represents the programmatic model that guided CSISS deliberations and initiatives.

This model recognises the key role that space plays in human society and in the structuring of social processes. The CSISS strategy acknowledged that nearly every domain of the social and behavioural sciences could benefit from concepts of spatial thinking and from tools of spatial analysis. Hence, beginning with core themes in the literature of the social sciences and with evidence of applications in meeting societal needs, CSISS designed programmes to provide infrastructure to help scholars to add spatial context to the prevailing practices, applications and theories of their disciplines.

Table 2.1 and the paragraphs that follow outline this formulation, with examples of themes identified in the work of social scientists. They include an itemisation of spatial perspectives and tools of potential value in addressing research about these themes, list programmes organised to help promote the development of tools and expertise appropriate for the social sciences, and suggest anticipated outcomes for judging the success of CSISS programmes.

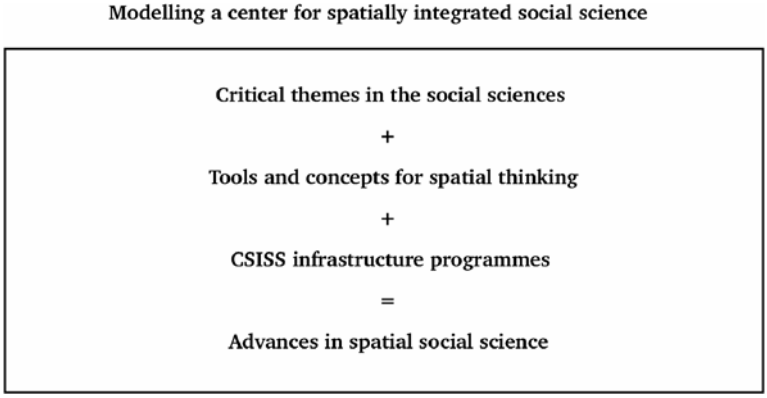

Fig. 2.1 Modelling CSISS

2.2.1.1 Themes

The thematic interests and theories intrinsic to the social sciences were the catalyst for establishing the kinds of spatial tools, concepts and programmes that would be of greatest service to researchers, instructors and practitioners. These themes span scales from the local (e.g. sense of place) to the global. They reflect needs that range from good description to prediction for promoting understanding and explanation of patterns of change and societal processes. They also touch upon all of the fundamentals for defining social wellbeing, including health, economy and political process. In addition, they reflect needs for methodological developments (e.g. risk assessment, flow data analysis and small-area analysis).

2.2.1.2 Spatial Tools and Concepts

The primary tools featured in CSISS programmes and publications were geographical information systems and data visualisation technologies. Spatial statistics were treated in association with spatial econometrics and exploratory spatial data analysis and made use of such software packages as GeoDa (Rey and Anselin 2006) and Geographically Weighted Regression (Fotheringham, et al., 2002). Tools and concepts related to traditional spatial analytic concerns, such as optimisation methodologies and analyses of interaction matrices, were supplemented with social science applications of agent-based spatial models, Bayesian spatial analysis and remote sensing.

2.2.1.3 CSISS Programmes

The key themes of social science research and the tools and concepts of spatial thinking were drawn together though a set of interrelated programmes of best-practice examples, web-accessible resources, training opportunities and expert meetings to push the development of applications and of new methodological tools.

Table 2.1 Infrastructure programmes to promote spatial methods and thinking in the social sciences

Integrating social science themes and spatial tools through CSISS programmes to achieve desired outcomes			
Themes	+ Spatial Concepts and Tools	+ CSISS Programs	= Outcomes
Human–environment interactions			
International conflict			
Equity	Agent-based spatial modelling	Specialist meetings	New applications
Health and disease	Analytical cartography		
Small-area analysis	Bayesian analysis	Workshops	Diffusion of spatial analysis
Cultural analysis	Dynamic visualisation		New journals
Globalisation		Tools development	
Risk assessment	Exploratory spatial data analysis		New social science resources
Demographic processes	Flow data analysis	Best-practice publications	International conferences
Space-time accessibility	Geographical information systems		
Governance		Learning resources	Advances in theory
Community organisation	Location-allocation modelling		
Externality effects	Point pattern analysis	Place-based search	New collaborations
Electoral processes	Remote sensing		
Crime and law enforcement	Spatial econometrics	Internet portal (www.csiss.org)	New programmes for funding research and training
Sense of place	Spatial interaction modelling		
Etc	Etc		

For example, CSISS-sponsored research-oriented specialist meetings drew participation from leading scholars in several fields to reflect on core issues in the social sciences. Eight separate meetings held in the period 2000–2005 engaged more than 220 leading scholars to explore gaps in knowledge and new potentials for spatial perspectives in science and planning.[2] They addressed traditional domains of social science inquiry (e.g. equity, risk analysis and health, spatial externalities in economics and globalisation) as well as new areas of investigation where spatial thinking and

[2] See http://www.csiss.org/events/meetings/specialist.htm for information on CSISS specialist meetings.

technologies might add value (e.g. location-based services that exploit GPS and wireless technologies, and the application of time-geography concepts in transportation planning). They identified scientific agendas and workshop needs for young scholars, proposed learning resources essential to the diffusion of tools and concepts, initiated the creation of new spatial research tools and explored dissemination practices to reach potential users of spatial methods. Meeting participants also fostered collaborative networks and helped in the development of best-practice publications of exemplary social science applications (Anselin, et al., 2004; Goodchild and Janelle 2004a). All of these programmes are described in detail at www.csiss.org, but two programmes – the workshops and tools development – deserve special attention.

Workshops

CSISS sponsored or cosponsored more than thirty intensive week-long or two-week-long residential workshops to introduce the latest and most authoritative approaches to the methods and tools of spatially integrated social science. Workshops help to advance cross-disciplinary collaborative networks among participants by stressing the commonality of the spatial perspective to problem identification and research approaches. The workshops were based on three distinctive but complementary strategies for national dissemination. The first was an integrative research strategy for workshops held in the years 2000–2004, which were devoted to meeting the immediate research needs of PhD candidates, postdoctoral students and untenured professors.[3] The second was a focused research strategy, exemplified by the 2005–2006 GIS and Population Science training programme (GISPopSci),[4] which targeted a large proportion of PhD students in a small discipline (demography). A third strategy was designed to address undergraduate instruction, as reflected in the 2004–2007 SPACE (Spatial Perspectives on Analysis for Curriculum Enhancement)[5] workshop programme. SPACE participants included undergraduate instructors from many disciplines who were committed to including spatial methods in their undergraduate teaching. All three strategies envisioned broad national dissemination through follow-up initiatives by participants (e.g. presentations to colleagues, research proposals, new courses and publications), all of whom were

[3] See http://www.csiss.org/events/workshops for information on CSISS workshops.

[4] The GIS Training Program for Population Scientists, was directed by Stephen Matthews and funded through Pennsylvania State University's Population Research Institute by an award from the National Institute of Child Health and Human Development (NICHD, R25 HD047744-01). In cooperation with CSISS, this programme offered two-week long workshops at UC Santa Barbara and at Pennsylvania State University. See www.csiss.org/GISPopSci.

[5] SPACE (Spatial Perspectives for Analysis for Curriculum Enhancement; http://www.csiss.org/SPACE) was funded by NSF through the Curriculum, Course, and Laboratory Improvement – National Dissemination programme of the Division of Undergraduate Education (NSF DUE 0231263). It was hosted at the University of California, Santa Barbara and directed by Donald Janelle. Workshops were held at UCSB, Ohio State University, San Diego State University, San Francisco State University and the University of Oklahoma.

Table 2.2 Workshops in GIS and Spatial Analysis by CSISS (2000–2007)

Number of	Participants	Applicants
Anthropology/Archaeology	59	123
Criminology	21	45
Demography, Population and Health	98	227
Economics	63	192
Environmental Studies	18	33
Epidemiology	11	27
GIS	30	75
History	7	10
Human Geography	123	422
Political Science	55	95
Public Policy	17	80
Regional Science	5	6
Sociology	115	200
Statistics	9	22
Urban Studies/Planning	44	133
Other	31	99
Totals	706	1789

selected on the basis of evidence of their success and potential as active researchers and dedicated teachers.

A total of 384 scholars participated in CSISS-sponsored workshops, another 324 benefited from workshops sponsored by CSISS through SPACE and GISPopSci, and several hundred more took part in CSISS-sponsored events at annual meetings of learned societies. These included special sessions and short workshops in association with many academic communities, including the Society for American Archaeology, the American Anthropological Association, the American Political Science Association, the Population Association of America, the American Society of Criminology, the Association of Social and Behavioural Scientists, the Association of Collegiate Schools of Planning, the Regional Science Association, the American Sociological Association, the Rural Sociology Society, the American Agricultural Economics Association, the Southern Demography Association, the Association of American Geographers, the Social Science History Association and the University Consortium for Geographic Information Science.

The disciplinary breadth of CSISS programmes is revealed by the diversity of associations mentioned in the previous paragraph. However, participation in residential workshops provides evidence of a significant commitment of academic energy by several hundred scholars from across the full range of social science disciplines and subfields (Table 2.2).

Spatial Tools

From its inception, CSISS was committed to the development of spatial analytic tools to serve the needs of social scientists. Under the direction of Luc Anselin and his team of software developers at the University of Illinois, Urbana-Champaign

(UIUC), this effort resulted in the creation of *GeoDa*™, released in 2003 as a freely available and easy-to-use software package to analyse spatial data and to account for such geographical effects as spatial autocorrelation and spatial heterogeneity. Rey and Anselin (2006) review the development and utility of *GeoDa*. Complementing *GeoDa*, Anselin's team established a web-based clearinghouse on tools for spatial data analysis and established a website for accessing tutorials and sample datasets (Anselin 2005).[6] They also contributed to spatial analysis components for the open-source R statistical software package.

GeoDa offers an interactive environment of dynamically linked windows for displaying spatial data with maps, statistical and exploratory data graphics, and tables. Its value for the social science community resides in its convenient interface and use of standard ESRI shapefiles, its capabilities to combine multiple simultaneous visualisations (e.g. maps, 3D representations, cartograms and parallel-coordinate plots), and its facility for assessing spatial effects and for implementing spatial regression analyses. The drawing of scientific inference from form (e.g. locational patterns) to process (e.g. space-time patterns) is an ambition that social scientists have long pursued. Although not seamless in its execution, *GeoDa* facilitates this valuable reasoning process. Workshop programmes through CSISS, the UIUC Spatial Analysis Lab, the Arizona State University GeoDa Centre and the Inter-university Consortium for Political and Social Research (based at the University of Michigan) have featured *GeoDa* for spatial analysis in the social sciences. Through such programmes and through direct downloads of the software (more than 40,000 by mid 2009), the *GeoDa* user base has expanded beyond initial expectations across dozens of disciplines and several dozen countries. It is now widely used for research and teaching.

2.2.1.4 Outcomes

Assessing the outcomes of CSISS programmes is complicated by the interactive and multiple efforts of many organisations (e.g. academic societies, businesses, foundations and government agencies), academic institutions and individuals, all of whom have shared in the task of disseminating new technologies and perspectives for scientific research and problem solving. Although important, CSISS is just one of many contributors to the development of tools and training programmes that have helped scholars with disciplinary theory and new applications. The efforts of several programmes (local, national and international in scope) have collectively built momentum for increased spatial awareness in science and society (Goodchild 2004).

Leading scholars from a range of disciplines have noted the heightened importance of spatial reasoning in transforming the fundamental understandings of the social sciences (see, for example, Knowles 2000; Lobao 2003; Colwell 2004; Butz and Torrey 2006; Voss, et al., 2006). In the United States, funding agencies, such as the National Science Foundation and the National Institutes of Health, have estab-

[6] Resources on general spatial analysis tools are available at http://www.csiss.org/clearinghouse/; the specific resources in support of *GeoDa* are at http://geodacenter.asu.edu.

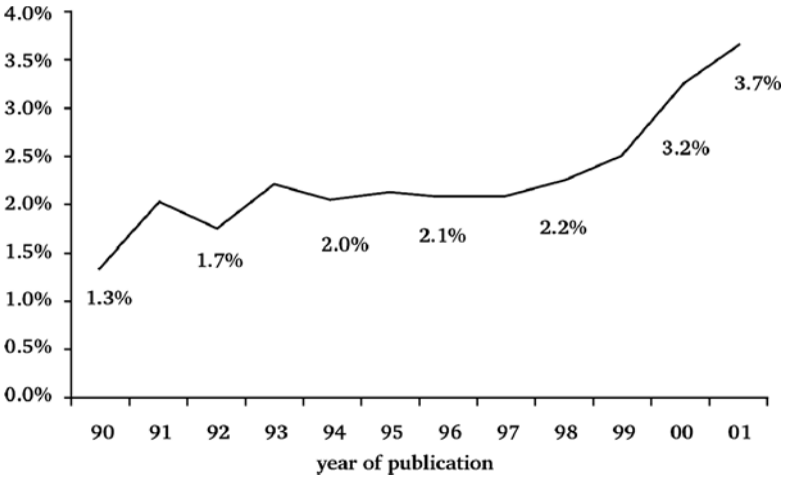

Fig. 2.2 Percentage of social science articles with spatial analytic themes 1990–2001 (source: CSISS–see details at http://www.csiss.org/resources/litsearch.html)

lished priorities to promote uses of spatial analytic tools across a wide range of research themes. For example, the Human Spatial Dynamics funding programme of the National Science Foundation issued a call for proposals relating specifically to spatial social science.

A CSISS literature analysis revealed a sharp increase in the proportion of all social science journal articles using spatial methods dating from around 1998 (see Fig. 2.2). Nonetheless, the percentage of such articles remained small relative to the potential and it was not clear in 2001 that the 'spatial turn' in the social sciences had reached a point of self-sustained growth. Importantly, Wilson's (2007) tally shows a continuation of the upward trend through 2005 in the use of spatial terminology in the titles and keywords of articles for social science journals.

Recent publications suggest that there is a growing momentum toward spatial social science. Journals in several disciplines have dedicated individual issues to exploring applications of GIS and spatial statistics, often arising from conferences attended by scholars form diverse disciplines and nationalities. Examples include *Social Science History* 24(3) (2000), *Agricultural Economics* 27(3) (2002), *Political Analysis* 10(3) (2002), *Political Geography* 21(2) (2002), *Proceedings of the National Academy of Sciences* 102(43) (2005) and the *American Journal of Preventive Medicine* 30(2) (2006). The 2008 launch of *Letters in Spatial and Resource Sciences* highlights the transdisciplinary and transnational nature of this transition and the need for an authoritative forum that can offer more rapid dissemination of research findings than traditional journals.

2.2.2 Documenting a 'Spatial Turn' in the Social Sciences

Special issues of journals, broad interdisciplinary participation in training programmes, new tools and easy access to spatial data all point to the momentum for

a 'spatial turn' in the social sciences during the past decade. The establishment of the new Research Network in Spatially Integrated Social Science, funded by the Australian Research Council, and the new SPLINT (Spatial Literacy in Teaching) programme in the United Kingdom, are evidence of strong nodes of dissemination elsewhere in the world.[7] Of special importance are new programmes set up at individual universities to nurture awareness and integration of spatial perspectives in research. Examples in the United States include Harvard University's Center for Geographic Analysis, Brown University's initiative on Spatial Structures in the Social Sciences and the recent establishment of spatial@ucsb – a spatial studies centre dedicated to promoting spatial thinking in all branches of knowledge – at the University of California, Santa Barbara. Another example is the University of Redlands, a small liberal arts institution with strong ties to the Environmental Systems Research Institute (ESRI). It seeks to place spatial tools, such as GIS, into the curriculum for access by all students. In Europe the SPIN (spatial information) Laboratory, serving both the Faculty of Economics and the Faculty of Earth and Life Sciences at the Vrije Universiteit Amsterdam, stands out with its multidisciplinary orientation and the integration of research programmes with regional, national and continental planning issues.

The growing popularisation of spatial tools also feeds the growing interest in spatial methods and in skills for informed spatial reasoning. The use of maps in print and visual media, the spread of geographical positioning systems (GPS) and vehicle navigation systems, the easy access to map and satellite imagery via geobrowsers (e.g. Google Earth™ and Virtual Earth™) and web-based mapping tools all point to a growing need for spatial perspective and for broad concern for education in basic spatial literacy. The increasingly widespread adoption of Web 2.0 practices (e.g. geotagging of information in WikiMapia®, voluntary citizen input of photographs to Yahoo's Flickr™, and other resources) reinforce these concerns. Against this background, a brief reflection on the CSISS programmes and strategies suggests lessons to consider in developing programmes to maintain the current momentum in the social sciences. Applications of these lessons may also encourage general spatial literacy for informed use of spatial tools embedded in the popular media.

2.3 Building Foundations for Spatial Thinking across Knowledge Domains – Lessons Learned

Although the roots of CSISS lie primarily within the discipline of geography and its links with the National Center for Geographic Information and Analysis (NCGIA), experiences since 2000 have exposed a much broader interdisciplinary interest in spatial methods. Out of this has come recognition of how the theoretical and thematic perspectives of diverse knowledge domains can contribute to and benefit from

[7] Information on Australia's Research Network in Spatially Integrated Social Science is provided at www.siss.edu.au; the SPLINT programme in the United Kingdom is described at http://www.le.ac.uk/cetl/splint.html and at http://www.casa.ucl.ac.uk/projects/projectDetail.asp?ID=66.

a more explicit focus on spatial thinking (Goodchild and Janelle 2004b). The lessons learned from the CSISS programme focus on the importance of diversity, leadership, action at local levels and the inclusion of fundamental spatial concepts in education.

2.3.1 Lesson One: Diversity as Strength

The diversity of interest from across disciplines adds to the value of spatial thinking for formulating theories and solving problems. Strength through diversity is achievable when scientists and communities of all kinds have access to the latest tools to find, analyse and evaluate information. An array of tools and a breadth of data sources, accessible to both professionals and lay populations, are especially important in the realm of geographical information. Location (including concepts such as place, space and time-space) may be seen as the natural context for the integration of information across knowledge domains to solve problems. The importance of location as a framework for organising, searching and retrieving information on any topic is demonstrated by the remarkable growth in use of geobrowser technologies and by the functionality of geodigital libraries (e.g. the Alexandria Digital Library).[8] The dissemination of spatial analysis beyond its core disciplinary origins requires multiple strategies for diversifying the user base and expanding the range of training programmes to serve students, professionals and populations of varying skill sets and educational needs. For CSISS, these multiple strategies included workshops for both researchers and teachers, meetings between experts to explore new research directions, web access to resources, publications and the development of new analytic tools.

2.3.2 Lesson Two: Leadership

Leadership in spatial thinking has its origins in different fields. Because of the importance of disciplinary structures in the administration of knowledge (and of academia), significant progress can be achieved if influential scholars within a field adopt leadership roles in the dissemination of spatial thinking and in the application of spatial tools. Using this leadership to form support networks that bring learners into contact with mentors can have a strong impact. In the dissemination efforts by CSISS, applications of spatial analysis by prominent representatives of specific disciplines were, in general, most persuasive in building support for spatial methodologies in specific research and teaching communities. Co-opting participants in training workshops and specialist research meetings as agents of dissemination is a very useful approach, providing it serves the participants and is valued by peers in their own disciplines.

[8] See http://alexandria.ucsb.edu/.

2.3.3 Lesson Three: Embedding Spatial Thinking in General Education

The experiences of working with several hundred participants in CSISS programmes and the findings of the National Research Council's report Learning to Think Spatially (NRC 2006) suggest a general need to address the absence of an explicit focus on skills in spatial reasoning in education at all levels. It is important to make the concepts of spatial thinking explicit and to provide illustrations of their applications. Examples should show how use of spatial thinking advances scientific understanding, facilitates problem solving in everyday life and fosters a deeper appreciation of the locational context of policy debates and conflicts at local, regional, national and international scales. CSISS programmes, especially its SPACE programme's focus on undergraduate instruction, viewed spatial thinking as a foundation for informed citizenship and for information analysis and assessment. A principal argument in support of such an initiative is that spatial perspectives offer a means of integrating theory within and across disciplines, and for matching theory with evidence. Spatial analysis can therefore provide a foundation for interdisciplinary cooperation, for example in seeking to understand the coupling of environmental and social processes in the study of planning problems at local and regional scales.

2.3.4 Lesson Four: Acting Locally

Putting spatial thinking to use is achieved most easily and cogently by acting at the local level. Local context provides opportunities in teaching for students to explore problems of tangible interest in their daily lives, to build expertise in the uses of data and tools to answer questions of importance to the community, and to gain appreciation for the relevance of spatially informed decision making. It is also important to position the study of localised problems and phenomena within the context of broader regional and global issues, a process easily accommodated through the application of spatial concepts such as location, scale, neighbourhood and spatial dependence.

2.4 Foundation Concepts for Spatial Thinking – A Geospatial Perspective

The list that follows represents a consolidation of more than two dozen distinct spatial ideas discussed by de Smith, et al., (2006) into a constellation of eight primary concepts. An objective is to position concepts and their importance to scientific reasoning as the driving force for the selection and use of spatial tools. In arriving at this listing, the focus is on ideas that are demonstrable at all levels of space and time (from subatomic to galactic, from the past to the future and from microseconds to ions). In general, the concepts should be understandable to young children in the form of simple illustrations, but sufficiently engaging at the most advanced levels

for thinking about scientific and social problems. Each should be expandable from a five-minute explanation to a lifetime career of research and application.

- *Location* – Understanding formal and informal methods of specifying 'where'
- *Distance* – The ability to reason from knowledge of relative position
- *Network* – Understanding the importance of connections
- *Neighbourhood and Region* – Drawing inferences from spatial context
- *Scale* – Understanding spatial scale and its significance
- *Spatial Heterogeneity* – The implications of spatial variability
- *Spatial Dependence* – Understanding relationships across space
- *Objects and Fields* – Viewing phenomena as continuous in space-time or as discrete

Concepts such as those listed above have been a foundation for researchers for centuries, enhanced in recent decades through the use of computational and visualisation tools and vast and easily accessible information resources.[9] Such concepts and tools need to be as central to general education as reading, writing and arithmetic. In conjunction with the appropriate spatial tools, they provide a basic scaffold for designing research, solving problems and structuring education programmes. This is the intent behind a recent initiative at the University of California, Santa Barbara.

2.5 Transitioning to Spatial Thinking through spatial@ucsb

Drawing from its experience as the primary host for the National Center for Geographic Information and Analysis (NCGIA) and its core curriculum project in GIS, from the lessons learned in the CSISS programme and from inspiration provided in the National Research Council's report Learning to Think Spatially (NRC 2006), the University of California, Santa Barbara launched spatial@ucsb in 2007. The mission of spatial@ucsb, a centre for spatial studies under the direction of Michael Goodchild, is to (1) facilitate the integration of spatial thinking into processes for learning and discovery in the natural, social and behavioural sciences, (2) promote excellence in engineering and applied sciences, and (3) enhance creativity in the arts and humanities. It goes beyond the focus on geospatial interests to integrate spatial thinking into the corpus of reasoning across all the domains of knowledge for research and teaching.

The centre is leading a campus-wide effort to frame curricula to equip UCSB graduates with concepts, methods and applications of spatial thinking appropriate to interdisciplinary and transdisciplinary communication, research collaboration and community need. This curriculum embrace the geospatial concepts listed above, but it also explores concepts (and tools) for spatial thinking in design fields and in

[9] See http://teachspatial.org.

the humanities and arts. Examples include the link between form and function in architecture, the search for pattern in speech and text, the use of spatial notation in music, the use of spatial metaphor in the sciences and humanities, the importance of place in cultural and social studies, and the spatial elements of aesthetics in the visual arts.

The centre provides a web portal to curriculum and learning resources and a web forum for the exchange of ideas and training opportunities for researchers and students.[10] Like its predecessor organisations (NCGIA and CSISS), spatial@ucsb promotes research on new tools and applications of spatial thinking. It sponsors advanced research seminars, specialist meetings and workshops to serve UCSB academic needs and to help stimulate research based on national and international collaboration.

2.6 Conclusions

Appreciation of the relevance of spatial perspective in science is augmented by a growing level of expertise in spatial methodologies on university campuses and in business, public-sector agencies and community organisations. The extent of this shift and the breadth of its influence on different areas of knowledge create conditions suited to the kinds of curriculum changes envisioned in this chapter. This is especially the case in the emergence of academic leaders as potential allies who see the need to imbue science education with the powerful insights of the spatial perspective and to position spatial thinking as important (if not essential) to scientific understanding and to sound public policies. There is, however, a need to document these transitions more fully than is possible in this chapter. There is need for a systematic and more complete monitoring of trends in the literature, of software adoption and of general scientific interest in the importance of locational factors in understanding processes.

The application of geographical technologies and its effective integration with information and communication technologies has made significant inroads into most of the social sciences and into the medical sciences. Interest in the role of location and space as fundamental frameworks for accessing, analysing and processing information has intensified through the rapid dissemination of web-based technologies and through innovations for visualising intensities, associations and connections across information sets. New tools, such as GeoDa and Geographically Weighted Regression, have helped move analysis to a new plane of discovery, but, nonetheless, technical and methodological obstacles still impede optimum use of geographical technologies. For instance, van der Wel et al. (2007) note that traditional geoscience tools (such as GIS) are data driven and based on static and discrete layers of information. As such, they are not easily adapted to meet the needs of some knowledge domains that lie outside the geospatial sciences.

[10] See www.spatial.ucsb.edu.

Technological enhancements for the integration of space-time data resources and for the analysis and display of longitudinal information are required to capture processes of scientific interest. As an ideal, one might envision capabilities for data analysis that match the current capabilities of agent-based spatial modelling and microsimulation to display space-time processes (Janelle 2005). Another possibility, following van der Wel et al. (2007), is to adopt aspects of meteorological modelling and visualisation for process-driven space-time displays.

In addition to the spatial concepts featured in Section 2.3, there is a need to accommodate other notions of spatial thinking – for instance, concepts of spatial cognition related to relative position, shape, size and orientation (Newcombe 2006). Moreover, if significant improvements in education are desired, support resources will need to be assembled, organised and made easily accessible, including exemplary course units, exercises and instruments for learning assessment. The value of achieving general spatial literacy is a goal worthy of such effort.

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