Spatial Learning in Geography
Presentation Abstracts

Presenter: **Tom Baker**

Poster: **Advancing GIS Education Research Through Community**

Abstract: ESRI is committed to *Advancing GIS Education Research* – educational research supporting and driving effective classroom instruction with geo-technologies (including Geographic Information Systems, positioning devices, remotely sensed imagery, etc.). One approach to this commitment is to support the *GIS Education Workgroup*, a group of about 40 researchers from academia, industry, and private organizations who wish to collaborate and better understand how geo-technologies can be more pedagogically effective tools. This workgroup is open, expanding, and meeting twice yearly to share current work, inspire colleagues, and organize a more coherent framework of research. Workgroup website: http://edgis.org/research

Presenters: **Robert Bednarz, Injeong Jo, and Sandra Metoyer**

Poster: **Spatial Thinking in Geography at Texas A&M**

Abstract: Several graduate students and faculty in the Department of Geography at Texas A&M have interests in spatial thinking. Although these individuals' interests are not identical, they overlap significantly. The participants at this workshop have research interests in the following areas.

Robert Bednarz

Several researchers (e.g., Golledge and Bell) have suggested that digital operations performed through GIS are, in many ways, analogous to the mental processes involved in spatial thinking and cognitive mapping. This viewpoint is also a theme in Learning to Think Spatially, in which GIS is touted as a technology that can support spatial thinking. If these assertions are valid, it is reasonable to hypothesize that GIS learning can improve spatial thinking. Unfortunately, the research literature has only just begun to investigate this situation.

Injeong Jo

Despite increasing interests in teaching spatial thinking skills, it is not clear what teachers should expect students to demonstrate as outcomes of spatial thinking. In addition, little is known about how teachers can incorporate aspects of spatial thinking into their lesson plans or test items more explicitly. Traditionally, in the field of education, taxonomies have been used to address such questions. As a "framework for classifying statements of what we expect or intend students to learn as a result of instruction" (Krathwohl 2002, 212), an educational taxonomy can be used to evaluate instructional activities and materials, to organize curricula, and to construct test items which require students to practice spatial thinking skills. A taxonomy of spatial thinking was developed in which three components of spatial thinking – concepts of space, tools of representation, and processes of reasoning – are embedded. The purpose was to provide a practical tool that can help teachers incorporate the three components of spatial thinking into their teaching practices in more explicit and systematic ways.

Sandra Metoyer

There have been exciting advances in understanding how spatial cognition develops, its importance to disciplines such as science, engineering, and geography, and the effects of training on spatial thinking

skills. However, we lack an integrated multi-disciplinary mode of spatial thinking to guide applied education research. To develop an applied theory of spatial cognition three critical elements are required 1) an operational definition of spatial cognition and identification of the underlying spatial skills, 2) a theoretical model of spatial cognition, and 3) empirical research concerning the effectiveness of interventions based upon the theoretical model of spatial cognition. The first two of these elements are included within a theoretical framework, the *Hierarchical Parallel Model* of spatial cognition, through the lens of an interdisciplinary and integrated foundation.

Presenter: **Richard G. Boehm**

Poster: **Geography: Teaching with the Stars**

Abstract: Geographic literacy is crucial to the future of America. Learning geography creates citizens who are able to understand and make decisions about some of the major issues and problems facing their communities, the United States, and the world. Americans need geographical knowledge, perspectives, and skills to maintain moral, political, and economic leadership in a world of complex cultural and environmental relationships. The purpose of this project is to contribute to geographic education at the middle/junior high and high school through the use of media-based professional development materials.

This project, tentatively called *Geography: Teaching with the Stars*, is a partnership between the Grosvenor Center for Geographic Education, the Agency for Instructional Technology, and the National Geographic Society Education Foundation. The primary purpose of the project is to demonstrate to teachers how geographic perspectives, concepts, and skills together with relevant instructional and assessment strategies can be used to improve students' ability to understand and deal with geographical issues. The project includes 20 DVD programs, an interactive website, and print materials for facilitators, teachers, and students. The DVDs, featuring real teachers in real classrooms, will focus on a specific topic (i.e. climate change) and pedagogical or assessment strategy (i.e. differentiated learning). This project is informed by current research on media-based professional development and will be similar to LessonLab Research Institute or Teachscape, two online, research-based professional development programs.

There are two phases of development, implementation, and evaluation for *Geography: Teaching with the Stars*. During Phase I, a prototype DVD will be developed and field-tested. This prototype will also be used for marketing purposes to secure funding for Phase II development and dissemination. In Phase II, the remaining nineteen DVDs will be developed with print materials, and materials will be disseminated to Geography Alliances, schools districts, universities, and other educational organizations.

The formative evaluation component will be conducted in cooperation with project staff, as the materials for each project element are developed, field-tested, and refined. This activity is expected to occur during a two-year period, beginning immediately after Phase II funding is secured. Emphasis during this period will be on providing meaningful, comprehensive information to project staff that allows for the development and refinement of the instructional designs, components, and constituent materials.

The Phase II research component will be conducted over a three-year period beginning during the first full semester of dissemination and use of the project in schools and other venues throughout the United States. This phase will focus on the short and long-term impact of the project materials on teacher growth and effectiveness and student learning.

Project staff for *Geography: Teaching with the Stars* are currently seeking funding for the project through federal and state funds as well as private foundations. Possible federal avenues for funding include NSF Discovery Research K-12 (for inservice teachers and K-12 students) or NSF Course, Curriculum, and Laboratory Improvement (for preservice teachers). While these federal funds would be used for the development, implementation, and evaluation of the project materials, additional funds will be sought from school districts, regional education service centers, universities, and private foundations.

Presenter: **Rick Bunch**

Co-Author: Robert Earl Lloyd

Poster: **Variations in Map-Reading Performance and Efficiency**

Abstract: The performances of tasks that require geographic knowledge are affected by both task demands and the cognitive resources available to individuals. The spatial information required for a given task might come in verbal and/or visual-spatial forms (Bosch, Mecklinger, and Friederici 2001). This information may be stored in a person's memory from prior learning experiences or acquired through perceptual processes from an external source (Sjölinder et al. 2005). It is also true that some spatial tasks are relatively easy to complete while others may be difficult. For example, a task that involves searching for a map symbol with a unique characteristic should be relatively easy while a visual search for a map symbol that shares characteristics with other map symbols should be relatively difficult (Bunch and Lloyd 2000; Lloyd 1997).

If the research goal is to explain the variation of performance on a map-reading task, one first needs to define success along with a specific task to be investigated. Two variables that are frequently used as measures of success in cognitive experiments are accuracy and reaction time. Accuracy is defined as the proportion of the decisions made that are correct while reaction time relates to the elapsed time between the stimulus presentation and response (Prinzmetal, McCool, and Park 2005). Since the person making a decision can control the processing, it is possible to trade off accuracy and reaction time (Rinkenauer et al. 2004). Together these two variables measure performance efficiency.

The purpose of this research is to examine the performance of a map-reading task that required subjects to locate a state on a map of the United States after being given the state's name. Response times and accuracy were hypothesized to be a function of differences among the decision makers and among the states. The cognitive science literature suggests that variation in performance can be explained by the interaction of biological and environmental variables. Individual differences in gender, working memory capacity and brain lateralization were hypothesized to affect performance of the spatial task. Results indicated gender could be a more informative variable than sex. Subjects who identified with both feminine and masculine characteristics had the fastest mean response times. Subjects who did not identify with feminine or masculine characteristics had the most accurate responses. Those subjects who combined higher verbal and spatial working memory capacities had both the fastest and most accurate performances. The results supported other studies indicating a non-linear relationship relating sex, brain lateralization, and accuracy. Covariates related to gravity model variables were also significantly related to performance.

Presenter: **Anjan Chatterjee**

Co-Authors: Prin X Amorapanth, Page Widick

Poster: **The Abstraction of Spatial Relations: Neural Observations**

Abstract: Humans represent spatial information in different ways. Presumably, these representations are structured to better serve perception, action or communication. We studied the neural basis of abstracted spatial representations motivated by the following framework. Objects in space are abstracted into categorical spatial relations. Spatial categories can be schematized to discard the sensory richness of objects. These spatial schemas retain analog qualities in the form of lines, surfaces and vectors. Spatial relations are also abstracted into symbolic referents in the form of prepositions. Thirty-four individuals with focal brain damage were tested on their knowledge of four categorical spatial tasks. These tasks probe their abilities to match 1) different pictures of categorical spatial relations, 2) pictures to schemas, 3) prepositions to pictures, and 4) prepositions to schemas. Using voxel-lesion-symptom-mapping (VLSM) techniques we found that damage within widely distributed networks involving the posterior parietal, dorsolateral prefrontal, and lateral temporal cortices bilaterally impaired categorical spatial abilities. Left brain damage produced greater impairment than did right brain damage ($F_{1,32}$=5.43, $p<0.05$).

The ability to match:

1) categorical pictures was impaired by damage to the left inferior and middle frontal gyrus, and left angular and supramarginal gyrus, as well as right angular, supramarginal and posterior middle temporal gyrus.

2) prepositions to schemas was impaired by damage to the left and the right middle temporal gyrus.

3) prepositions to pictures was impaired by damage to the left angular, superior temporal and middle frontal gyrus as well as the right angular gyrus and inferior frontal regions.

4) pictures to schemas was impaired by damage to the right middle temporal damage.

Performance on tasks matching prepositions to schemas and pictures to schemas correlated highly (0.59). Damage to the left middle occipital gyrus and the posterior superior temporal gyrus accounted for unique variance in mapping prepositions to schema deficits, whereas damage to the right posterior superior temporal gyrus accounted for unique variance in matching pictures to schemas. Performance on matching pictures of categorical relations and matching pictures to schemas correlated highly (r = 0.74). Damage to the right middle temporal gyrus accounted for unique variance in performance for matching schemas to pictures. Performance on matching preposition to pictures and of prepositions to schemas was also correlated (r = 0.57). Damage to the right posterior superior temporal gyrus accounted for unique variance in preposition to schematic matching. Again damage to the right middle temporal damage accounted for unique variance in preposition to schematic matching.

These patterns of combined and distinct patterns of spatial knowledge vulnerabilities to neuronal damage suggest the following organization of abstracted spatial relations. While the left hemisphere is biased to process categorical spatial relations, both hemispheres are involved. The left angular, superior temporal and middle frontal gyrus serves as a network that mediates categorical forms of spatial representations (pictures, schemas and prepositions). The right hemisphere distinguishes between analog representations (pictures and schemas) whereas the left hemisphere distinguishes between representational formats (analog versus verbal spatial representations).

Presenter: **Roger M. Downs**

Poster: **The Role of Expertise in Spatial Thinking**

Abstract: As someone who has worked for a long time at the intersections among geography, education, and developmental psychology, I have been fascinated by a pair of apparently simple questions: How does expertise in spatial thinking develop? How might we foster the development of such expertise in a knowledge domain?

As a discipline, Geography draws heavily on the skills identified with spatial thinking: while those skills are essential to Geography, they are not unique to it. However, section 3.8 of *Learning to Think Spatially* (2006) indicates that it is possible to analyze exemplary pieces of geographical scholarship in terms of the role of component spatial thinking skills. The subsequent sections, 4.2.1 and 4.2.2, discuss the role of domain-specific expertise.

Over the years, in both teaching and research contexts, I have used a prototypical map-completion task to explore the role of domain-specific spatial thinking skills as they intersect with domain-specific knowledge. (The task is drawn from the work of a brilliant geographer, William Bunge, *Theoretical Geography* (1962.))

The task is simple: a participant is given a line-drawing, black-and-white map that has, in effect, been torn in half. The challenge for the participant is to (a) complete the missing portion of the map and then (b), through think-aloud procedures, to explain the rationale for the choices made while completing the map. Participants have ranged in age from eight years and up and in level of expertise from novices to experts in geography (both teachers and research scholars.)

The results show several things including: (a) the differences between purely graphic solutions to the task through to truly geographic solutions that rely on a sophisticated componential pattern analysis; (b) the role of map stereotypes in shaping expectations and responses; (c) the misunderstanding of scalar relationships; (d) the differences between the processes of interpolation and extrapolation in 1-d linear and 2-d areal contexts; and (e) the role of specialized, domain-specific knowledge in recognizing patterns, generating expectations, identifying anomalies and deviations, drawing inferences, and seeing relationships across pattern components.

The task has several advantages: (a) it can be used over a wide range of ages and levels of expertise; (b) it has face (and perhaps some degree of ecological) validity; (c) it can be used for both teaching and research; and (d) the map can be redesigned to tap into the intersections between a range of spatial skills and different areas of domain-specific knowledge. More importantly, however, it is indicative of the need to develop authentic tasks that can be used to develop domain-specific expertise in educational contexts.

Presenter: **Scott M. Freundschuh**

Poster: **Funding Opportunities at NSF to Facilitate Translation of Research Findings on Learning to the Classroom**

Abstract: The National Science Foundation supports activities that facilitate the translation of educational research findings into classroom settings. These activities can entail formal and/or informal learning processes. The goal of these activities is to enhance K-12 and college level learning. This presentation will highlight NSF Programs in DR-K12 (Discovery Research K-12), REESE (Research and Evaluation on Education in Science and Engineering) , ISE (Informal Science Education), ATE (Advanced Technological Education), ITEST (Innovative Technology Experiences for Students and Teachers), RET (Research Experience for Teachers), REU (Research Experiences for Undergraduates), and ROA (Research Opportunity Awards) Supplements.

Presenter: **Dedre Gentner**

Co-Authors: Benjamin D. Jee, David H. Uttal, Dedre Gentner, Bradley Sageman, Cathy Manduca, Carol J. Ormand, Thomas F. Shipley, and Basil Tikoff

Poster: **Using Comparison to Facilitate Perceptual Learning of a Geoscience Concept**

Abstract: Geoscience education plays a central role in developing students' understanding of the relationships between physical, chemical, and biological processes, and how they affect environmental change at both local and global scales. One important component of Geoscience education, especially at the undergraduate level, involves teaching students the perceptual skills involved in identifying geologically-relevant structures in *outcrops*, the parts of a rock formation that are visible at the earth's surface. The identification of these structures allows the student to build a hypothesis about the geologic history of a particular area, make predictions about future geological change, and develops their more general understanding of Earth processes. The present research explores the conditions that support students' learning of an important geological concept, *fault*, which is a fracture in a rock along which movement has occurred. In textbooks and lectures, students may be provided with multiple examples of faults, with the intention that they will learn a general concept that will apply across a wide range of contexts. Over the course of learning, students are exposed to a variety of different examples, and are faced with the nontrivial task of determining the relevant characteristics of faults in general.

Our study considers the role of comparison processes in this learning. Comparison involves aligning the structural commonalities of two or more representations (Gentner & Markman, 1995; Markman & Gentner, 1993). When comparison involves highly similar (alignable) items, noticing *alignable differences* (readily comparable features that differ between the items) may be facilitated. This suggests an interesting educational application: the comparison of highly similar outcrops, where only one contains a fault, may facilitate students' ability to identify faults in general. In this study that tested this prediction, participants were presented with a sequence of 20 pairs of images, each image depicting an outcrop with multiple layers of rock. Only one of the images in each pair contained a fault. The participant's job was to determine which one. We contrasted two learning conditions: (1) a *similar-first* condition, in which participants were given 10 trials in which similar images were paired, followed by 10 trials in which dissimilar images were paired, and (2) a *dissimilar-first* condition, in which the 10 dissimilar pairs preceded the 10 similar pairs. Following the learning phase, participants were presented with a transfer task involving a sequence of 14 single images. The participant had to decide whether a fault was displayed in each one. If they responded yes, they were then asked to determine the fault's location by placing two

Xs over it using the computer mouse. If initial comparison of highly similar items facilitates people's rapid learning (Gentner, Loewenstein, & Hung, 2007), then participants in the similar-first condition should show more accurate performance in the both the learning phase and the transfer task. The results were consistent with this prediction, particularly for participants who had previous experience in a Geoscience course. Classroom tasks that involve visual comparisons of geoscience structures may therefore provide a useful tool for teaching students the perceptual skills required in the field.

Presenter: **Phil Gersmehl**

Co-author: Carol Gersmehl

Poster: **Test Scores Associated with Lessons Designed to Teach Spatial Thinking**

Abstract: This project has two loosely overlapping phases: a thorough review of research, and development and testing of educational activities. The goal of the research review was to define a concise list of spatial-thinking skills that could be viewed as "common ground" for (at least) three groups: geographers describing the process of interpreting a map or other spatial representation, developmental psychologists exploring the process of learning, and neurobiologists identifying specific brain structures or connections that appear to be involved in spatial thinking. A candidate idea could be included on the list if met three criteria. First, it must involve a kind of map analysis that was identified in at least two books on map interpretation. Second, it must be the subject of several behavioral studies that focus on the development of this kind of thinking. Third, at least one fMRI, PET, rTMS, or lesion study has identified a specific brain area that appears to be implicated. The list was presented for review at several professional conferences in late 2005 and early 2006 and then published in December, 2006 (Gersmehl and Gersmehl 2006).

After the review was submitted, but before it appeared in print, we used the list as the basis for several sets of lessons that explore geographic aspects of issues that appear in other courses, such as history, earth science, or GIS applications. We also designed a complete set of Kindergarten and first grade lessons for a 9-classroom charter school in Harlem, New York. Unlike the middle- and high-school lessons, which were intended as supplements for existing courses, these primary-school lessons were conceived as a year-long course of study, for the simple reason that the school chose to allocate one 40-minute class period per week to geography.

In collaboration with teachers and administrators, we suggested a schedule that would devote roughly four weeks each to nine sets of related lessons, with each set having a primary focus on one specific mode of spatial thinking from our taxonomy. We made a serious attempt to link these lessons with ongoing classwork in language arts and math, by identifying vocabulary terms and math concepts that could be "co-taught" with each geography lesson.

It was impossible to compare these classes with a "control group," because few schools in New York City teach geography as a standalone subject at that grade level. All we can say is that scores on standardized tests in both language arts and mathematics rose sharply. Scientific integrity precludes any claim of a direct cause-and-effect link between our geography lessons and higher reading and math scores. But we can sleep comfortably, knowing that we have honored the doctor's Hippocratic Oath: "Above all, do no harm!" In short, we can say that a weekly geography lesson in primary school appears to have done no harm to reading and math scores (and, by the way, these kids really know how to read a map!)

Presenter: **Michael Goodchild**

Poster: **Spatial@UCSB: Perspectives for Teaching and Research.**

Abstract: In mid 2007 the University of California, Santa Barbara established a Center for Spatial Studies, alias spatial@ucsb, to promote and integrate the use of spatial thinking across the campus. The center offers workshops, seminars, symposia, and conferences; provides assistance with software and data; operates a teaching facility; and is constructing a set of online resources. An extensive survey and set of interviews has established the surprising prevalence of spatial thinking in virtually all campus programs, from Religious Studies to Nanoscience, and has identified over 100 faculty with significant interest in the application of spatial perspectives in teaching, research, or both. Scales vary from nano to cosmic, and approaches range from the humanistic and artistic to the scientific and technological, while the spaces of interest include those of the human brain and those constructed through the spatialization of non-spatial data.

Earlier this year the center co-organized a small workshop to explore the potential of a program of curriculum development at the undergraduate level. The spatial concepts used in the many disciplines intersected by spatial@ucsb form a body of discrete ideas that could be the subject of well-developed curriculum at the undergraduate level, with suitable support from software. In the geographic domain, these are the concepts that underlie the use of GIS, and that also appear in the disciplines that address the design of geographic spaces. Curriculum materials might be aimed at freshman seminars, general-education courses, or courses in disciplines that need to address one or more specific spatial concepts. In December the center is co-sponsoring with ESRI a specialist meeting to explore whether the spatial concepts that underlie critical thinking with GIS also are appropriate to education in the design-oriented disciplines of planning and landscape architecture.

We see this project as essentially complementary to the work of cognitive psychologists on the acquisition of spatial concepts, and look forward to the kinds of collaborations that this meeting will stimulate.

Presenter: **Robert Kolvoord**

Poster: **Where the Map Hits the Road: Implementing GIS in the K-12 Classroom**

Abstract: My interest in this area is multi-faceted, I would like to find ways to explore how to best provide professional development to teachers in the use of geospatial technologies across the curriculum, including building their spatial thinking skills; I'm curious how the various curriculum activities have landed in classrooms and what their impact on student spatial thinking skills might be; I want to complete work on a scope and sequence of activities that span grade levels and content areas to promote spatial thinking and geospatial technology use in K-12; and I'd like to also better understand how what the implication of working with young adults (18-24) to better move materials back and forth between K-12 and post-secondary settings.

Over the last fifteen years, I've been involved with a number of professional and curriculum development projects that have brought me into contact with hundreds of K-12 teachers and that have led to the development of a wide variety of lessons, mostly in STEM disciplines (but with a growing number in social studies). In the professional development area, I think we have a real opportunity to better understand teachers' spatial thinking skills and how to augment them and help them build the pedagogical content knowledge and technical pedagogical content knowledge to effectively take advantage of the various geospatial tools (including GPS units, various Google tools – Google Earth and Google Maps,

GIS software, etc.). We have a growing number of teachers with varying stages of experience and some intriguing opportunities for researc

On the curriculum front, I'm particularly interested in the GIS-based activities from our recently released Rural STEM collection of activities for middle school students (http://www.isat.jmu.edu/stem) and the activities in the book I wrote with Kathryn Kernanen, "Making Spatial Decisions Using GIS". I'd like to help develop a field-tested set of best practices to share with other curriculum developers to maximize the usefulness of our efforts in classrooms. I've also been working on developing a scope and sequence for the implementation of geospatial technologies across grade and content level in K-12. I'm interested in learning more about how students' spatial thinking skills evolve as they move through K-12.

I also have a somewhat unique group of students that have been participating in the Geospatial Semester that might provide fodder for a research study. These students take coursework in their high school during their senior year that focuses on geospatial technologies. They also pursue an in-depth research project of local interest and for this effort, they earn college credit at JMU. We have more than a dozen schools participating in the current year (the 4th year of the project) and I'm interested in how this experience informs their future decisions about higher ed and career possibilities.

Presenter: **Kim Kastens**

Poster: **An Oceanographer's Approach to Spatial Thinking and Learning in Geography**

Abstract: My education and early career were in marine geology, a branch of Ocean Sciences. During that era of my life, I spent nearly two cumulative years at sea on oceanographic research cruises making maps of the bottom of the ocean, and trying to figure out the tectonic and sedimentary processes that had shaped the seafloor. More recently, my research interests have shifted to spatial thinking in geosciences, as part of my larger professional goal of creating a public that knows more, understands more, and cares more about the Earth and environment.

In my talk, I will touch briefly on several projects that involve spatial thinking:

- "Where are We?" software and curriculum development project: helping children learn to translate back and forth from a map to the real world they see around them (collaboration with Robert McClintock, Teachers College).
- Children's map skills project: examining 4th graders' strategies and mistakes as they attempt a simplified version of the field-scientists' task of locating observations onto a basemap (collaborative with Lynn Liben, Penn State).
- Artificial outcrops project: examining how scientists and undergraduates perceive, record, interpret, integrate, and convey spatial information from rock outcrops (collaborative with Lynn Liben)
- Climate forecast maps: examining how environmental policy students interpret (and misinterpret) maps showing probabilistic forecasts of future precipitation (with Toru Ishikawa)
- Seafloor maps: examining how 8th -12th grade students interpret a map of bathymetry and topography, including how the map was made and what it is useful for (with Sandra Swenson).

In conclusion, I will offer for discussion my candidate for the most interesting and important unanswered question in spatial thinking.

Presenters: **Susan Levine and Kristin Ratliff**

Poster: **Improving Children's Understanding of Units of Measure: A Training Study**

Abstract: Measurement links the abstract world of numbers and the concrete world of physical objects. However, assessments indicate that measurement skills lag behind all other mathematics topics (National Center for Education Statistics, 1996). Although elementary school children typically respond correctly when an object is aligned with the zero-point of a ruler, they respond incorrectly when an object is not aligned with the zero-point. In this case, students simply read off the number where an object ends or count the number of hash marks between the start and endpoint of the object (Bragg & Outhred, 2004; Ellis, Siegler, & Van Voorhis, 2001; Lehrer et al., 1998). This suggests that children do not fully understand the concept of a unit as they do not know what is being counted.

In the current study, we introduced a training method to highlight the importance of units on a ruler. By showing students how and what needs to be counted (i.e. the *intervals* on the ruler, rather than the numbers themselves) we aimed to demonstrate that reading off the end number and hash mark counting are not correct strategies. Twenty-six second grade students completed a pre-test of 16 measurement items (8 aligned with the start of the ruler and 8 misaligned). In a second session, students played a measurement game with the experimenter. Half of the children were randomly assigned to the intervention training, where they measured items located at various points on a ruler (e.g. aligned and misaligned with the "0" point) using discrete units placed directly onto the ruler. The control condition was designed to replicate traditional measurement instruction with aligned items, using the same ruler <u>*or*</u> units from the training condition but not both together. The task for both conditions was to give the lengths of the objects. All children were given a post-test immediately following the experimental session and a follow-up post-test one week later.

The intervention training significantly improved performance on misaligned items compared to the control condition. The effect was maintained following a one week delay. Further analyses revealed strategies differences related to performance. Specifically, children who employed the read off strategy at pre-test were not improved after training while children who counted hash marks directly benefited from training even after one week. Thus, the training effectively changed those who employed the counting hash mark strategy to counting units. Using discrete objects superimposed on a ruler is an effective method for instructing measurement that highlights the fact that units are countable by making each unit extremely salient. These results have direct implications for instruction in mathematics, whereby emphasizing unit intervals (e.g. using units in conjunction with a ruler) can effectively enhance children's understanding of linear measurement units. Applications of these results extend to geography learning whereby students must use scales that are not directly aligned with the map content to infer distance information. Early intervention in measurement instruction can improve understanding of units and transfer to better scaling ability in using maps.

Presenter: **Lynn S. Liben**

Poster: **A Developmental Psychologist's Approach to Spatial Cognition in Geography**[1]

Abstract: *As a developmental psychologist, my work is aimed at understanding the ways that people come to think abou*t space and at exploring the implications of this developing spatial cognition. More specifically, my research is aimed at (a) describing ways in which concepts of space change with age and with various kinds of experiences, (b) identifying dramatic variations among people in spatial skills or concepts or in their success in using them for everyday tasks (e.g., map-based navigation) and for educational and professional challenges in the sciences (especially in geography and geology), (c) understanding how soon and why variations emerge among individuals and between groups (especially groups defined by gender), and (d) developing educational interventions that are aimed at building students' underlying basic spatial skills and concepts, activating existing but under-used skills, or adapting instruction to accommodate students' less well-developed skills.

In my 4-minute (high speed) presentation and poster, I will share a number of studies (both completed and ongoing), most of which involve collaborations with colleagues from geography, geology, or education. Although describing several studies precludes giving detail about any one, I have taken this path to illustrate how my general interests and methods apply to the kinds of questions likely to be of interest to workshop participants who hail from traditions and fields other than developmental or cognitive psychology.

- **Developing Map Concepts and Map Skills:** *design and delivery of a 5-week unit on mapping to classes of children (K-G6) to catalogue development of basic map concepts and skills, and to examine relations between individuals' spatial skills/concepts and map understanding (in collaboration with geographer Roger Downs).*
- **Accounting for Success on the National Geographic Bee:** *examination of what individual qualities (including spatial skills) are linked to students' success on the Bee (in collaboration with geographer Roger Downs, in partnership with Mary Lee Elden, Director of the Bee at NGS).*
- **Spatial Skills and Location Mapping:** *examination of children's success in placing stickers on maps to show flags' locations in a field setting in relation to children's spatial skills and task qualities (in collaboration with geologist Kim Kastens and developmental psychologist Lauren Myers).*
- **Spatial Skills and Geological Concepts:** *examination of college students' success in understanding geological concepts of strike and dip and in representing rock outcrops on a campus map in relation to students' spatial (horizontality) concepts (in collaboration with geologist Kim Kastens and developmental psychologist Adam Christensen).*
- **Educational Interventions and Mapping Success:** *examination of effects of the Where Are We? curriculum (developed by Kim Kastens) and of effects of "self-explaining" instructions on children's success on location-mapping tasks (in collaboration with geologist Kim Kastens).*
- **Map Exploration in a Museum Context:** *examination of parent-child interactions at The Children's Museum of Indianapolis (TCM) during visits to the NGS MAPS: Tools for Adventure! exhibition, including study of how interactions vary with children's and parents' spatial skills (in collaboration with developmental psychologists Lisa Szechter & Lauren Myers; in partnership with TCM exhibit developer, Cathy Donnelly).*

[1] I thank NSF, NIE, and NGS for support of one or more of the projects described here, although no endorsement by any funding agency is implied.

Presenter: **Amy Lobben**

Poster: **Behavioral and Neurological Correlates of Spatial Thinking**

Abstract: In this poster, I present results from three projects (some ongoing and some complete). While these projects focus on different populations (sighted and blind) and utilize different research methods (behavioral and neuroimaging - fMRI), the common link between them is human input of geographic information and processing of information acquired from geographic maps. Including multiple populations and utilizing traditional laboratory, field behavioral testing, and neuroimaging may provide a deeper, more robust understanding of geographic information input, processing, and use.

Project One investigates navigational map use behavior and abilities. In this project (Lobben 2007), subject performance on a laboratory-administered test instrument battery was compared against performance of in-field map use tasks. Test instrument reliability and criterion validity was assessed. Performance on individual test sections was also compared to overall navigation performance and significant relationships were observed for some tasks. Continued and ongoing testing has revealed a potential construct I am calling Performance Patterns of map use behavior and ability. My ongoing research results suggest that considering map use ability based on performance on discrete map use tasks, may not capture the full spectrum of map use behavior and ability. By using batteries of tests that include several measures of different map tasks, I am beginning to identify populations that exhibit similar patterns of multiple task performance.

Project Two (which includes three studies) investigates neural patterns associated with map use and performance patterns using tasks from the reliable and valid instrument developed and tested in Project One, above (Lobben 2007). In Study One (Lobben, Olson, and Huang, 2005), we selected two test sections, self-location and map rotation, and pilot tested ~50 volunteers. From the pilot testing, a second group was selected based on performance. These subjects then performed the two tasks again while undergoing fMRI. Results reveal significant differences in neural patterns associated with performance of the two geographic tasks. In Study Two (Lobben and Lawrence, in process), we again selected a task from the navigation instrument developed and tested in the Project One. Over 100 subjects were recruited and performed several mental rotation tasks, including rotation of: maps with text, maps without text, simple geometry, complex geometry, and text alone. Behavioral testing results reveal significant differences between rotation of each of the different stimuli except text alone. Again, a subset of subjects was selected based on performance patterns; they completed the tasks again while undergoing an fMRI. In Study Three (Lobben, Lawrence, and Olson, in progress), we again selected two tasks from the navigation test instrument (Lobben 2007), pre-tested ~70 subjects and selected the top 10 and bottom 10 performers and performed fMRI while subjects again completed the tasks.

Project Three investigates spatial abilities and geographic data input and use by map users who are blind and includes three studies. In Study One, we (Lobben, Lawrence, and Fickas, in review) have developed and field validated standardized tactile navigation map symbols. Validation of our tactile symbology included laboratory and field testing with map users who are blind. In Study Two, we (Lobben, Lawrence, and Fickas in progress) again recruited map users who are blind and administered a battery of tests including map survey memory, geometric and map rotation, and a BTSOD (Blind Traveler's Sense of Direction survey, adapted from the Santa Barbara Sense of Direction survey). We compared performance on the in-laboratory administered test battery to in-field map use tasks. Study Three is underway and is investigating thresholds for discriminable tactile thematic map symbols.

Presenter: **Andrew J. Milson**

Poster: **Spatial Visualization and Analysis in High School Geography: Comparisons of Internet-based GIS and Desktop GIS**

Abstract: There are numerous options available for high school geography teachers seeking to infuse geospatial technologies into their classrooms. Yet all geospatial technologies are not created equal. As with any technology, each tool is designed to serve a particular purpose. Some geospatial technologies are designed primarily as tools for visualization. These technologies offer students and teachers quick access to maps and graphs. Internet-based Geographic Information Systems (IGIS) websites and virtual globes such as GoogleEarth are excellent options when visualizing maps and geographic data patterns is the goal. These geo-visualization technologies offer important benefits for teachers. No software must be purchased and installed on school computers, many of the websites are updated with real-time data, and the interface is usually easy to navigate. There are disadvantages associated with IGIS though. Most importantly, a more powerful tool is usually needed when the instructional goals call for analyzing and evaluating geographic data, applying problem-solving skills to real-world decision-making, or constructing understanding through creative and critical thinking. The geospatial technologies designed as tools for analysis offer students and teachers the power and flexibility to explore the "whys of where" in a real-world context. The most common geo-analysis technology is a desktop-GIS such as ArcView or MyWorld. There is a role for both geo-visualization technologies and geo-analysis technologies in the geography classroom, but each technology should be used in a way that matches its intended purpose. In this presentation, I will summarize my research on the use of geospatial technologies for spatial visualization and analysis with high school geography students.

Presenter: **Daniele Nardi**

Poster: The Relationship Between Geometric Shape and Slope for the Representation of a Gowl Location in Pigeons (*Columba livia*)

Abstract: The ability to use the geometric shape of the environment to orient in space and locate a goal has been shown in many vertebrate groups. Experimentally, however, spatial tasks are typically carried out on a horizontal surface. The present study explored the importance of the vertical dimension for representing a goal location and how solving a geometry task is affected by the presence of a vertical component in the environment. In a reference memory task, pigeons were trained to find a goal in an acute corner of an isosceles trapezoid arena, which could be placed on a flat or on an inclined surface. In Experiment 1, learning the task on a slope proceeded more rapidly than on a flat surface, presumably because of the additional kinesthetic, vestibular and visual information extractable from the inclined surface. Although the geometric shape of the arena was encoded, pigeons trained on a slope were almost exclusively relying on a goal representation based on the vertical and orthogonal axes of the slope to solve the task. In Experiment 2, pigeons learned the geometric shape of the arena at a similar pace whether training occurred on a slope or not, indicating a lack of cue competition between slope and shape geometry. In Experiment 3, pigeons were trained with three different orientations of the arena on the slope. Subjects encoded the shape of the environment; however, when tested in a novel arena orientation, pigeons did not generalize what they learned and did not choose the geometric correct corner. Surprisingly, however, they made systematic errors to the other acute, mirror image corner. It is hypothesized that this systematic error reflects the encoding of multiple orientation-specific slope-based goal representations during training. Overall, the present study showed, for the first time, that a slope gradient exerted stronger control over goal searching behavior than the geometric shape of the environment. Furthermore, it indicated that pairing the more salient slope cues with the less salient geometric cues did not overshadow geometric learning, but produced a peculiar effect, such as the failure to generalize geometric cues in a novel orientation.

Presenter: **Thomas F. Shipley**

Co-Authors: Shannon Fitzhugh, Alexandra B Morrison, Jason Chein, & Nora Newcombe

Poster: **Training Mental Rotation: A Comparison of Training Spatial Skills and Working Memory**

Abstract: Effective use of complex spatial visualizations requires specific visual skill and more general cognitive skills, such as encoding, transforming, and comparing spatial relations. The poster presents research from the Spatial Intelligence and Learning Center on training the skills used for spatial visualizations. There are two important implication of our findings: 1) Not all spatial visualizations users will have similar skills and thus may have very different levels of success in extracting intended information from any given visualization. 2) An individual's skill level is not fixed; both domain general and domain specific spatial skills are malleable and may be trained.

In the domain of cognitive skills working memory is recognized as playing an important role in general intelligence. Working memory refers to the ability to keep things in memory while performing other cognitive operations. An example of a working memory task would be remembering a list of items presented in alternation with solving mathematical equations. Understanding and manipulating spatial visualizations requires working memory: For example, one might need to remember the meaning of particular symbols on a map, while also searching the map for particular relations, such as cities near water.

We have found significant differences across individuals in ability to encode and transform spatial relations (for example, imagine what an object looks like from a different viewpoint), and working memory capacity (numbers of items one can keep in mind while engaging in other cognitive tasks). We have found that encoding efficiency and working memory capacity can both be increased with training. Encoding efficiency as indexed by the pattern of eye movements increases with training and generalizes from one type of 3D visualization to another. Working memory training had broad cognitive benefits; it increased attention to important information and generalized broadly, to facilitate spatial visualization.

Presenter: **Michael Solem**

Poster: **A Teacher's Guide to Modern Geography**

Abstract: In September 2004, the AAG received a $515,927 grant from FIPSE to provide geography teachers with a suite of high-quality training products that a) are adaptable to the curricular standards of every state, b) emphasize spatial thinking skills, and c) satisfy the needs of pre-service programs as well as early- and mid-career teachers.

One of the major outcomes of the project is a *Teaching Geography* CD, which is included in the second edition of the book by Phil Gersmehl (Guilford Press). The CD is also a completely independent, stand-alone resource. Through 80 interactive multimedia units, the CD illustrates key modes of spatial thinking – such as pattern analysis, spatial transitions, hierarchies, site and situation, and region – and how these concepts are used by geographers to examine environmental, political, social, and economic issues in major world regions. Each unit is supported by notes for teachers that explain the spatial concept and how it can be used to develop classroom presentations and student activities. The CD also provides examples of student activities to help teachers get started, as well as a complete set of state geography standards.

Earlier drafts of the CD material were extensively tested by K-12 teachers, college geography faculty, and educational methods instructors. The result is a bounty of material that can help geography educators and teacher trainers in both schools and higher education. In addition, the companion web site offers downloadable packets of workshop materials for teacher professional development in geography, math, science, and history. The workshop materials were developed in collaboration with the National Council for Geographic Education with input from science, math, and social studies educators.

Presenter: **David Uttal**

Co-Authors: Linda Liu Hand and Nora Newcombe

Poster: **How Much Can Spatial Reasoning be Improved: Results of a Meta-analysis**

Abstract: Spatial skills are critically important to the practice and teaching of geography. Our goal was to determine to what extent spatial skills can be improved through practice, training, or life experience. To address this question, we conducted a meta-analysis (a systematic, empirical review of research) of 113 research studies that attempted to improve spatial reasoning. We investigated the magnitude, moderators, durability and generalizability (i.e., transfer) of training effects. After eliminating outliers, the average effect size (using Hedges' g) for training, relative to control, was .65 (SE = .02). Effect sizes were affected substantially by the presence and type of control groups. When we considered treatment and control group improvements separately, the mean effect size for trained groups was g = .75 (SE = .03). Treatment group effect sizes did not differ for children (g = .70, SE = .05) and adults (g = .77, SE = .03) or for males (g = .58, SE = .06) and females (g = .59, SE = .06). Training effects were stable and were not affected by delays between training and post-testing. Perhaps most importantly, what was gained during trained transferred to other tasks, and hence the benefit of training was not limited only to the specific skills that participants had learned. Considered together, the results suggest that spatially enriched education could pay high dividends in terms of increasing participation in mathematics, science and engineering.

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