NSF Program:
Transitions from Childhood to the Workforce

White Paper

"Spatial Learning in Formal and Informal Settings"

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WHITE PAPER

INTRODUCTION

The fundamental question investigated during the course of this workshop was: what are the skills and knowledge structures that today's learners will need to acquire to make a successful transition to the workforce in the 21st century? This workshop was organized largely around the spatial and geographic skills and knowledge base that are part of that acquisition process.

As the information and technology age comes to fruition, an increasing amount of data accessed via different electronic modes is being spatially referenced. Spatial referencing simply means that geo-coded elements in the data relate information to a place which leads to the types of places that are identified as and conform to a Digital Earth metaphor. For the future workforce participant to comprehend and utilize such information to its fullest, that participant must be spatially enabled. Spatially enabling the workforce population involves having sets of spatial abilities developed during the course of the K-12 and collegiate educational experience, as well as developing an understanding of the fundamental geographic language and concepts that are embedded in the digital earth metaphor.

In a workshop conducted in the Santa Barbara area on Sept. 10-11, 1999, questions relating to the spatial skills and abilities necessary for transition to the workplace were examined by a group of 30 multidisciplinary experts (see Final Report for final list of attendees). Using a procedure pioneered by the National Center for Geographic Information and Analysis (NCGIA) which involved panel discussion, audience participation, breakout groups for intense small group discussion of specific problems followed by general discussion of recommendations and positions, the workshop identified a number of researchable questions and subsets of problems associated with those questions. This white paper presents a summary of the two general foci of the meeting along with the general research topics that the group deemed critical along with specific research questions within each critical topic.

Section A: Integrating Research and Education in the Spatial Domain

The first day of the meeting was devoted to discussing the integration of spatial cognition research into education. Our overall goal was to identify current knowledge that would be helpful to educator and or is deemed critical to successful transition to the workforce. We also wanted to identify gaps in our understanding of spatial cognition (both developmental and mature) that should be examined to better serve the education community.

Research Question # 1: What are the workforce implications of social, economic, governmental, and technological changes that will occur in the early part of the 21st century?

This question stimulated discussion to try to determine minimum sets of spatial and geographic skills that will be need to successfully enable a person to make the transition from childhood to the work force. Specific problem areas include:

- Identify enduring spatial tasks that have a high probability of continuing to be important to workforce participation in the next century. Examples included: ability to understand relative and absolute location; application and comprehension of different frames of reference; ability to identify spatial distributions and to comprehend how such distributions develop in terms of their internal spatial relations; spatial search including human navigation and wayfinding in the real world, in desktop and immersive virtual systems, and through complex organized systems such as the Internet and the World Wide Web; travel planning, including the ability to understand national and global relations among places and the characteristics and positive-negative factors associated with those places; as globalization and the development of international technological corporations increases, the ability to understand different cultures and the way they are expressed on the landscape in addition to obtaining language proficiency will be necessary; the ability to think graphically so as to comprehend various forms of data representation; the ability to use and interpret graphical, map, and imagery based representations of spatial and non-spatial information exhibited in two or three dimensions.
- Spatial tasking and geographic knowledge will become more common as globalization of business, industry, government, and society takes place as a result of changes in information and communication technology.

- The types of information best transmitted through different media and experienced through different modalities requires immediate determination.
- The degree to which the symbology used to represent information in the spatial domain can be comprehended and used requires considerable research.

Research Question # 2. How can we make children and adults more discerning consumers of spatial and geographic representations of information? How can we make age-based spatial and geographic training and learning available anywhere, anytime, anyplace?

- What are the more appropriate ways for interfacing formal/informal learning about spatial and geographic concepts and problems?
- What specific spatial problems lend themselves more to formal (educational) or informal (common experience) learning situations?
- What are the minimal necessary sets of spatial skills for understanding different problems and forms of representations (e.g., cartographic maps; remotely sensed images; still photographic slides; dynamic video/movie presentations; onscreen animation)
- To what extent can information processing currently undertaken in the visual domain be replaced or supplemented by information processing in the haptic, auditory or other sensory domains?
- What are the fundamental geo concepts that will need to be learnt to participate fully in the future workforce environment that is dominated by geo-referenced digital databases? (e.g., location; orientation; spatial distribution; spatial pattern; direction; distance; spatial sequence and order; enclosure; region; paths; boundaries; network; hierarchy; dominance; edge; spatial category; and scale).
- What are the necessary non-spatial skills required for interpreting and using different representational forms?
- How do we assess the significance for employment and productivity of the learning of specific spatial concepts and constructs?

Research Question # 3. What are the spatial and geographic skills necessary for effective participation in an age based on information transmission via electronic technologies? Some suggested research topics are:

- Defining the necessary spatial constructs that are indicative of geographic skills (e.g., rotations and translations; scale transformations; two dimensional to three dimensional transformations [and vice versa]; ability

to retain visual information over time; ability to conduct analogical reasoning in the spatial domain; use of symbolic representation; comprehending risk avoidance cues involved in spatial interaction; developing appropriate cognitive collages; translating from the vertical to the horizontal [and vice versa]; understanding objective and subjective absolute and relational frames of reference).

- Using and understanding spatial analogies, including the ability to discern when they are spatial and non-spatial.
- How compatible are the non-coordinate reference frames currently being developed (e.g., GOTO systems) with information access and display needs now and in the future?
- How pervasive is the spatial domain?
- How are multiple modes of perception related to space perception and cognition individually?
- What spatial domains are best represented egocentrically versus allocentrically? Or with other frames of reference (object centered, environment centered, etc.)

Research Question # 4: What is spatial thinking? Some suggested areas of potential research include:

- Articulation of what spatial thinking is in the context of what is known about spatial abilities.
- Application of spatial abilities to spatial and non-spatial problem solving situations.
- A reexamination of the concept of spatial abilities to examine different types of spatial relations in addition to the dimensions of rotation and orientation as well as the application of spatial abilities in different spaces and situations.
- How is spatial thinking assessed?
- To what extent do spatial abilities enter into education and learning in different disciplinary areas?
- How does one set up a spatial problem-solving scenario?
- What teaching strategies are most appropriate for encouraging learning in the spatial domain?
- How is spatial thinking taught in an information environment free of ethnic, cultural, minority disadvantaged or disabled biases?
- At what levels should and can spatial thinking be developed and enhanced?

- How do we teach teachers how to think and teach spatially and geographically?
- How do we encourage learning in spatially disabled individuals?
- What are the different forms of spatial disability (e.g., topographic amnesia; topographic agnosia; and selective brain damage)?
- What are the common denominators of spatial thinking?

Research Question # 5: In what situations are spatial representations more valuable than reality? Examples of questions to be investigated might include:

- To what degree and in what situations is first hand (i.e., experiential) spatial knowledge/information necessary?
- How real or how approximate does a representation have to be before it is taken as adequately representing a real situation?
- Do people learn and perform tasks the same in virtual and real worlds?
- To what extent can virtual displays enhance our understanding of the real world at different scales?
- To what extent can virtual systems replace the real world or laboratory based scientific experiments?
- Can the essential elements of representations solely in visual form satisfactorily reflect real world situations?
- To what extent and in what circumstances are visual, auditory, or haptic experiences substitutable for each other in the spatial domain?
- How can we enhance the comprehension and use of different forms of spatial and geographic representation?
- What are the essential differences between spatial and geographic modes of thinking and learning?
- Are the cognitive processes involved in spatial and geographic thinking the same, or is there a scale effect in the use of spatial cognition concepts?
- What is the minimal set of spatial concepts (e.g., location, spatial distribution, spatial pattern, spatial hierarchy, spatial proximity, spatial linkage, spatial network, region, edge, boundary, spatial dominance/subordinance) deemed necessary for future workforce participation?
- For a given set of representations, what are the set of spatial concepts that they best communicate or represent?
- What is the nature of individual differences with respect to the comprehension and use of spatial representations?

- To what extent do individual differences explain differences in the ability to understand spatial and geographic concepts?
- What is the role of representation of spatial concepts at different scales; are certain types of representations best for specific scales of communication or information transmission?
- How will our ability to understand future changes in the way we create spatial and geographic representations drive our teaching and learning experiences?
- As the ability to create more realistic representations improves, how will our ability to understand them change?
- How can comprehension and use of representations be optimized or improved?
- In what ways do our abilities to use/comprehend representations change with human development?
- Are there optimal forms of spatial representation with specific age groups?

Research Question # 6. What are the implications of spatial learning for those who are disabled?

- What are the different forms of spatial disability?
- What are the specific disabling features of topographic amnesia, topographic agnosia, and selective brain damage?
- What are the segments of the brain most closely associated with spatial and geographic understanding; do these areas differ between males and females?
- Do spatial learning disabilities have equal or similar effects in real and virtual environments?

Research Question # 7. How do we assess/evaluate whether or not people are gaining the necessary spatial skills from educational practice? Examples of the questions that could be pursued follow:

- What is the impact of technology on assessment; how will it change the way assessment is done?
- How do we assess the effects of newly developing technology?

Research Question # 8. What spatial skills are not geographic? Specific questions that are subsumed under this general area include some of the following:

- How do we differentiate between spatial and geographic?

- Are there geographic concepts that are non-spatial? What are they?
- Are there spatial concepts that are non-geographic? What are they?
- Given a list of spatial skills, how does each relate to the accepted dimensions of spatial ability?
- To what extent does our knowledge of spatial ability gained from the Bartree experiments translate into abilities to solve spatial problems in the real world?
- What critical features of spatial ability at relevant for real world work environments (e.g., pattern recognition, wayfinding/route learning; travelling salesman problems and distance minimalization in two or three dimensional environments; direction following ability; ability to make shortcuts/detours/obstacle avoidance without losing one's awareness of current position and place; ability to do spatially rational trip chaining involving multiple destinations; the ability to spatially classify and categorize on the basis of internal similarity or perceived internal similarity; understanding layouts and configurations of spatial phenomena; comprehending scale and scale transformations; comprehending conservation of space; ability to comprehend views from different perspectives; shape recognition; spatial change detection; comprehension of spatial representation; understanding the complex layers of different environments; thinking in spatial metaphors and analogies).

SUMMARY

As society transforms into a global information based and technology driven system, the need to understand the spatial concepts and spatial constructs on which information storage and transmission are based will inevitably become more important. This importance is being recognized in many disciplines as technologies such as geographic information systems (GIS) become thoroughly integrated into the activities of business, industry, and government. Spatially referenced digital databases are now common for storing not only map or image items in our libraries, but also the general textual content of libraries is becoming both stored and accessed more commonly in digital form. Card catalogues are being frequently replaced by computer based search engines. To find information about places, it is now becoming more feasible to access that information in iconic, analogue, or symbolic representational form and to display it on computer screens.

While such screens remain two-dimensional flat surfaces, many disabled groups will be more and more disadvantaged by being denied access to the same information and learning that is becoming increasingly more widespread and transparent for those with sight. Those spatially disabled by disease or brain damage for example will likewise become more disenfranchised. Thus it becomes essential, as we make a transition into the 21st century, to ensure that multimodal forms of interaction with digitally stored and spatially referenced material is made possible. The problems emphasized in this first section of the White Paper represent complete or partial lists of research needs. It is hard to identify one subset of questions as being more important than others. However it is obvious that there is a continuing need for research to define the nature and type of spatial abilities on the one hand and on the other hand an equally great need to understand how spatially referenced information can be best represented to facilitate spatial thinking, spatial learning, and increased geographic awareness from all facets of the population. Overall it is obvious that a prime direction for basic research over the next decade will be to concentrate on how different populations can be spatially enabled. It is equally apparent from this workshop and from general societal trends that the need for understanding of digital worlds will be enhanced as those worlds can be presented as structures that are already within the realm of human experience. The digital earth metaphor that is dominating geo-referencing of general information at this stage is one that can be readily comprehended, by those with both special education and general knowledge of environments and their characteristics. Each of these however can be enhanced by restructuring curricula in the K-12 and college teaching programs to emphasize spatial thinking, spatial problem solving, and the development of fundamental spatial skills and abilities. The question remains however how best to do this, and while some suggestions for areas of research in this direction have been identified above, the next section will focus more explicitly on the teaching and educating of different populations as they transition from childhood to the workplace.

Section B: Teaching and Learning Concepts in the Transition from Childhood to the Workplace

Part of the Santa Barbara workshop was explicitly devoted to examining the ways that spatial and geographic concepts and constructs can be taught and learned across the lifespan. When considering the transition from childhood to the workforce in the 21st century the question immediately arises as to how we can assess or evaluate whether or not the educational system is providing people with the necessary future skills from current educational practices. Much of our assessment is directed towards finding whether or not children are able to learn curricula. But what evidence do we have that the curricula that are being pursued in the K-12 classrooms are suitable for equipping graduating students not just for entry but for constructive participation in the future workforce?

Research Question # 1: One of the most relevant questions within the educating domain is whether or not teaching practice today focuses on teaching technology as opposed to teaching with technology. Not incidentally this leads to other relevant questions concerning whether or not the technology that is being taught and the technology that is being used can be appropriately assessed in terms of their future impacts. Specific problems to be pursued relating to these questions include:

- In the spatial domain, what technology is most appropriate for developing the relevant skills and abilities that will give those entering the future workforce the background and training needed to participate in an increasingly technological world?
- How can we improve the implementation of technology in the teaching environment?
- What technologies that are becoming available in the near future (i.e., 5-10 years) will most effectively help transitions to the workforce?
- How can we evaluate the ability of the existing cadre of teachers to understand and teach the concepts, language, and content of spatially relevant materials?
- Do we have to develop new teaching and learning procedures given the changing nature of information and data in an increasingly digital world?
- How can we assess children's progress towards a valid post-formal education workforce experience?

Research Question # 2. How will learning about spatial relations and spatial representations improve the ability of children to make the transition to the future workforce?

- Are domain general or domain specific approaches more relevant to the teaching of spatial information?
- What are the relations between spatial representations and spatial relations and characteristics of number systems or verbally based systems?
- How can we facilitate the increasing and necessary use of spatial representations in classrooms (e.g., especially non-visual forms such as auditory, haptic, kinesthetic)?

Research Question # 3. What spatial and geographic skills will be necessary in an information society in which information is digital and spatially geo-referenced?

- What are the spatial concepts that must be understood and the spatial abilities necessary for tomorrow's world as opposed to today's world?
- What are the critical spatial and geographic skills that appear increasingly necessary to understand information access in an increasingly digital world? (suggestions include scale; dimension; perspective; reference frame; digital representation; multimodal representation; spatial search; spatial distribution; spatial orientation; navigation; and planning).
- How should the above concepts be incorporated into educational systems?

Research Question # 4. To what extent do children vary on a range of continua in the classroom? Relevant questions include:

- What are the meaningful continua found in most classrooms (e.g., behavior; attention; leadership; cooperation; visualization; strategy development; spatial reasoning; object identification; specifying individual roles within a group context)?

Research Question # 5. How do we ensure bias-free teaching environments? Some possible responses include:

- Breaking away from a single strategy approach to teaching and learning.
- Adopt multiple strategies capable of producing similar solutions to the same problem.
- Adopt multiple solutions for a single problem as well as for multiple problems.

- Adopt problem based experiential learning procedures.
- Make problems relevant to children.
- Get involved in rotational participatory activities (e.g., where children adopt different roles under different circumstances).

Research Question # 6. What spatial skills are required for an age of technology?

- What new skills or abilities are likely to develop as a result of increasing use of technology.
- What are the limitations of technology for problem solving and instruction?
- How can we make the teaching of geography and spatial skills and ability easy for the teachers to implement?
- What are the desired outcomes of such educational activities?
- What new pedagogical developments can bridge geography and other subjects focusing on the spatial domain?
- How is it possible to incorporate experiential and problem based teaching into normal classroom practice?
- What are the characteristics of good geography teachers?
- What are the characteristics of good teachers?
- How are the characteristics of good teachers related or how are they different from the characteristics of good geography teachers?

SUMMARY

In this section we have focused on a number of relevant problems associated with teaching geographic skills and concepts, and developing the spatial abilities needed for an easy transition into tomorrow's workforce. Most of our recommendations follow a very traditional mold. If the aim is to improve teaching methods we must, improve how teachers are trained; incorporate more problem solving procedures into the learning process; understand more clearly the difference between using technology to teach and teaching about technology for use, and understand what the characteristics of good geography/spatial concept teachers are in comparison to the generally accepted dimensions of what constitutes good teaching.

Obviously an important part of ensuring that a smooth transition takes place from the educational system to the workforce involves developing curricula and teaching methods that are forward looking, relevant, and productive. Before venturing into these explorations however, we also need to undertake

an assessment of whether today's methodologies, learning scenarios, and curricula are doing as effective a job as can be expected or as is needed. Only by highlighting whether their current activities and procedures fail or fall short will we focus attention on specific processes that will enhance education, enhance teaching and learning, and enhance the probabilities that the smooth transition from educational environment to the workforce will take place.

FINAL STATEMENT

It was the consensus opinion of the group attending the meeting that the issues discussed were of importance for facilitating transitions from student life to the workforce. Further, the group understood the relationship between and importance of basic research and the practical application of results, particularly with respect to education. At the same time there was agreement that practical applications are not the only reason for developing and conducting basic research programs. Practical applications can be the result of years of painstaking research and should not be an expectation of all research agendas. In addition to the production of research questions that can be developed as researchable projects at a variety of scales (Ph.D. dissertations, 2-3 year NSF research grants, careers, etc.) there was also scattered yet important discussion of methods for conducting such research. This was not the defined purpose of the meeting, but the excitement concerning education related applications and the congruence of the meeting participants resulted in wide ranging discussions covering many issues related to basic and applied research.

The research questions developed at this meeting and summarized in this document represent the vision of leaders in the fields of developmental psychology, spatial cognitive and education. The recommendations (stated as research questions) can be used to guide research and exploration in basic and applied topics in each of these broad academic categories. Many of the research questions generated, and the discussions during the weekend meeting, were inter- and multi-disciplinary in nature. In keeping with this atmosphere there was agreement that future research should also pursue a goal of interaction between disciplines and that that greater breadth of motivations, methods, analysis and interpretation can result from projects receiving input from, and being designed by, scientists with divergent backgrounds.