CONCEPTS OF SPACE IN SPATIAL THINKING

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Abstract

Introduction

The topics “spatial thinking” and “spatial literacy” are recurring themes in discussions about Cartography, Geography and GISc. Defining spatial thinking is not easy though and although there are several definitions around, none of them addresses the matter of spatial concepts adequately.

The paper starts out with the assumption that a study of the nature of spatial concepts should start by investigating the most basic of spatial concepts.

Objectives

The objectives with the paper is firstly to describe the discovery of a meaning of spatial thinking by investigating the notions of schemata, concepts and basic spatial concepts.

The second objective is to show a way in which a person’s understanding of the basic concepts of space can be revealed in order to facilitate later research into the influence of understandings of basic concepts on interpretations of spatial representations and reasoning.

Methodology

In the paper deductive inference is used to combine various viewpoints from a philosophical viewpoint of concepts, anthropological linguistics, semiotics, cognitive schema theory and conceptual metaphor theory into a theory of spatial concepts.

The paper then summarises Kelly’s personal construct theory to clarify the meaning of a construct as used by Kelly. It introduces the repertory grid technique devised by Kelly to elicit and analyse constructs briefly to facilitate understanding of the research strategy advocated later.

A research strategy is proposed which consists of a sort of reverse construct elicitation and applying the repertory grid to analyse it. The hypothesis is that if the theory formulated earlier holds, this should be possible and the analysis should make sense.

Results

The results of some preliminary studies using the strategy is discussed, as is an interpretation of the results. These are positive, although not conclusive yet, since the research has not been completed.

Conclusions

It is concluded that the repertory grid and basic conceptual metaphors may be viable for inferring the nature of a person's understanding of basic spatial concepts but that it needs to be extended to higher level conceptual metaphors to be useful in inferring the implications for teaching and learning spatial representation and reasoning.

INTRODUCTION

The topics "Spatial Thinking" and "Spatial Literacy" are recurring ones in discussions concerning Cartography, Geographical Information Science (GISc) and science in general. All over the world programmes are being or have been instituted to teach "Spatial Literacy" and "Thinking Spatially" in primary, secondary and higher education institutions.

Yet, accurately describing "Spatial Thinking" or "Spatial Literacy" is a rather elusive endeavour. Definitions for the ideas are abundant and differing in content and detail, especially when it comes to spatial concepts.

It is contended that thinking about spatial thinking should start at the basic concepts of space.

The paper searches for the meaning of spatial thinking by investigating the notions of a schema, a concept and basic spatial concepts. It looks at the similarities between the theories about schemata and personal constructs and how language have an influence on spatial perception and spatial interaction.

It then offers a theory that, hypothetically, may be applied to see how different people understand the basic concepts of space and discusses the results of preliminary pilot studies to test the theory.

Understanding how learners comprehend spatial concepts is crucial in the education process. It determines the style and format of the educational delivery where the generally accepted modes of spatial representation and reasoning is taught.

SPATIAL THINKING

Ishikawa and Kastens (2005) gives an all encompassing descriptive definition of spatial thinking incorporating recognition, mental manipulation, interpretation of processes, prediction and using spatial metaphor for non-spatial thinking. Linn and Petersen (1985: quoted in King, 2006, p. 26), to the contrary, gives a rather simplistic definition namely "…representing, transforming, generating and recalling symbolic, nonlinguistic information".

The Committee on Support for Thinking Spatially (2006, p.12) (the Committee) defines spatial thinking as "…a constructive amalgam of three elements: concepts of space, tools of representation, and processes of reasoning." The American National Research Council (ANRC) is also quoted on the website of the Science Education Resource Centre (2008): "Spatial thinking is thinking that finds meaning in the shape, size, orientation, location, direction or trajectory, of objects, processes or phenomena, …"

Working from the definition of the Committee (2006, p.12), it is a relatively easy task to isolate what tools of representation, e.g. maps, and processes of reasoning, e.g. interpolation, are. The problem is with the "concepts of space", the "meaning", part of the definition. The Committee lists, *inter alia*, "…the basis of coordinate systems (e.g., Cartesian versus polar coordinates), the nature of spaces (e.g., number of dimensions [two- versus three-dimensional])…" (Ibid, p.12).

On Concepts and Schemata

According to Fodor (1998) all concepts are innate. Humans acquire concepts by interacting with phenomena or objects in the world and the concepts are formed according to the unique sensory experiences of the interaction. In his example, for instance, we acquire a concept RED by interacting with phenomena or objects that have the property of being red, because of the way our senses and minds work. The concept RED is innate, because the senses and mind are innate. Note that this concept formation has nothing to do with the articulation of the concept in a language. It is simply a construction of the concept (Von Glasersfeld, 1995) in the mind of the observer.

In a semiotic sense, once we learn a word or phrase for the concept, say RED, and using Peirce's (1931-58; quoted in Candler, 2004) triadic model of a sign, the concept would be the *interpretant*, the construction of the concept in our mind. The word or phrase itself he called the *representamen* or *signifier* (Chandler, 2004) whereas the *object* would be the red colour of the object referred to.

Foley (1997) demonstrates convincingly that "…languages have fundamentally different ways of describing spatial information and that these differences are systemically related to… differences in cognition…" (p. 228), which can be detected in psychological tests. (p. 229) He also cites convincing evidence that "…experience in the

form of expressive devices for spatial information provided by the language one learns and speaks play a critical channelling role in the way one habitually thinks about, recognizes and remembers spatial concepts." (p. 228)

To further understand concept formation, one needs to look at mental schemata. "A **schema** (plural: **schemata**) is a mental model, a way of understanding the world, a set of assumptions or understandings about reality". (Embree, 2009)

Donna Peuquet (2002, p. 81) explains the mainstream view of a schema by quoting Thorndyke (1986, p.167). He describes it as "a cluster of knowledge representing a particular generic procedure, object, percept, event, sequence of events, or social situation. This cluster provides a skeleton structure for a concept that can be …filled out(,) with the detailed properties of the particular instance being represented."

A mental schema provides a mental model to which events or objects can be compared in order to understand which concept will be appropriate. The concept is then structured to fit the particular instance. Lakoff and Johnson (1980/2003) are of the persuasion that it happens through conceptual metaphor. They have an amusing account of how the concept ARGUMENT can alternatively be structured through the conceptual metaphors ARGUMENT IS WAR, or ARGUMENT IS A DANCE and the consequential actions of the contenders. (p. 4)

To paraphrase Thorndyke (1986), the mental schema for argument provides the skeleton structure for the concept that can be filled out with the detailed properties of the particular instance of a difference of opinion and structured through the suitable conceptual metaphor to decide on appropriate subsequent action.

Schemata, and therefore concepts, are hierarchically and inter-relationally structured, (MacEacren, 1995; Lakoff & Johnson, 1999; Peuquet, 2002). As such it implies that they must emanate from certain primitives or "…'basic level' of concepts, that arises in part from our motor schemas and our capacities for gestalt perception and image formation." (Lakoff & Johnson, 1999, p. 77)

Lakoff and Johnson (1999) contend that "(s)patial relations concepts are at the heart of our conceptual system." (p. 30) The basic level conceptual metaphors, emerging from the basic spatial relations concepts, in turn serve as the building blocks for complex conceptual metaphors used in abstract thinking, subjective judgement, experience and reasoning. (Lakoff & Johnson, 1999)

The hierarchical and inter-relational nature of schemata and concepts "…allow us to conceptualise abstract concepts on the basis of inferential patterns…" (Lakoff & Johnson, 1999, p. 77) which allows us to acquire new knowledge.

From the above a theory of spatial concepts can be inferred:

- Although spatial concepts are innate, they can be viewed as sparse general representations of reality, tied together with mental schemata, which can be filled out as the situation demands, according to the appropriate conceptual metaphor.
- The *signifier* (word) used in language to signify the *interpretant* (spatial concept) of the *object* (spatial relation) plays a critical role in the formation of the structuring spatial conceptual metaphor and in the subsequent understanding and application of the concept.
- If we want to investigate personal concepts of space, we have to start with the basic level spatial concepts, since they are the foundation of the whole spatial conceptual system and will influence the rest of the hierarchical and inter-relational structure.

Note that none of the previous perspectives imply that *all* concepts and schemata can be expressed in words. A person may hold any number of concepts and schemata which he or she simply has no equivalent linguistic sign for. However, since those can only be investigated indirectly, they are not a consideration in this research.

Basic Level Schemata

Lakoff and Johnson (1999) identify three schemata, amongst others, as particularly basic.

The first is the "Container Schema" (p. 31), which uses signifiers like "inside", "outside", "across", "on" etc. It consists of a metaphorical "inside", "outside" and a "boundary". It allows us to conceptualise inter-relationships between objects in space and ourselves and other entities. It is argued that the basic concept that will activate the schema could be *position relative to a boundary*.

The second is the "Source-Path-Goal" schema (p. 32). It uses signifiers like "towards", "away from", "close to", "far from" and "path". In its most basic form it is a conceptualisation of movement with a point of departure, something that moves and an end destination. Here it is argued that the basic concepts that will activate the schema could be *position relative to a source and goal, movement, displacement, orientation, direction* and *conceptual distance*. Conceptual distance refers to the innate concepts like far, near and close by.

Thirdly, bodily projections (p. 34) uses signifiers like "in front of", "behind", "at the back of", "up" and "down". It projects concepts of our own bodies onto objects, like the front of a car, the back of a church, behind a tree, above, on top of and below or under. Again it can be argued that the basic concepts involved could be *position relative to an object, position of objects relative to the person, horizontal and vertical, forward and backward* and *orientation*.

It is argued that all the spatial relations concepts in italics above arise from our sensory-motor schemas and our capacity for gestalt perception and image formation. They are therefore basic level spatial concepts. Note that the capacity for object recognition does not form part of the spatial concepts. It is part of a different set of mental schemata. (MacEachren, 1995)

Note also that the basic level spatial concepts are devoid of conceptual metaphors. They are all literal, experiential concepts from which basic level conceptual metaphors are derived. The basic level conceptual metaphors in turn serve as the building blocks for complex conceptual metaphors as mentioned earlier.

Which brings us back to the problem with the Committee's (2006) clarification of concepts of space. It is too advanced in the conceptual hierarchy.

Cartesian and polar coordinate systems, for instance, are extensions of the basic container and source-path-goal schemata, using conceptual metaphors, to numbers are points contained on a line, space is a container for a set of discrete points and an origin as the source with a point as a goal. The concept of angles is a complex blend of metaphors consisting of 4 metaphorical domains. (Lakoff & Núñez, 2000).

Dimension and distance, on the other hand, are extensions of the metaphor "space is a set of points" and characterised by "formal statements" (Lakoff & Núñez, 2000, p.264). The metaphor "space is a set of points" are derived from the container schema which gives rise to the primary metaphor "space is a container", while formal statements would be instances like the definition of the length of a metre and definitions of length, width and height.

These are not basic concepts of space, but concepts that have to be constructed according to complex conceptual metaphors and formal statements, i.e. learned concepts, the understanding of which is subject to the nature of the linguistic signs used to communicate the basic concepts, between cultures and amongst cultural societies. (Von Glasersfeld, 1995, pp. 49 – 51; Lakoff & Johnson, 1999, p. 77)

It is argued that, in order to understand how a person thinks about space, it is necessary to firstly comprehend their understanding of the basic concepts of space and their usage in primary spatial conceptual metaphors.

CONSTRUCTIVE ALTERNATIVISM AND PERSONAL CONSTRUCT THEORY (PCT)

In the 1950's George Kelly (1963) put forward a theory that would "avoid the problems that are created by the implied assumptions of mental energy in push and pull theories of psychology". (Ibid., p. 44) He was probably referring to the widespread behaviourism of the time.

His theory of personality "…would also provide a universal accounting for the alternatives a man selects in a choice situation. It would recognise individuality by lifting each datum from the realm of the individual man…" (Kelly, 1963, p.45).

Kelly dubbed his philosophical standpoint "Constructive Alternativism" from his assumption "…that all of our present interpretations of the universe are subject to revision or replacement" and that "…there are always some alternative constructions available to choose among in dealing with the world." (Kelly, 1963, p. 15)

From his initial philosophical position Kelly (1963) developed a psychological theory which he called the "psychology of personal constructs" (Kelly, 1963, p. 46). He did this by stating a "(f)undamental postulate" which he elaborated with 11 corollaries.

Kelly's fundamental postulate is: "*A person's processes are psychologically channelized by the ways in which he anticipates events*." (Kelly 1963, p. 47)

The following two corollaries are pertinent to this research: (Kelly 1963)

- "*Construction Corollary*: A person anticipates events by construing their replications." (p. 103)
- "*Dichotomy Corollary*: A person's construction system is composed of a finite number of dichotomous constructs." (p. 103)

Kelly, (1963, pp. 8-9) introduces his *constructs* thus:

> "Man looks at his world through transparent patterns or templets (*sic*) which he creates and then attempts to fit over the realities of which the world is composed. The fit is not always very good. Yet without such patterns the world appears to be such an undifferentiated homogeneity that man is unable to make any sense out of it. Even a poor fit is more helpful to him than nothing at all.
> Let us give the name *constructs* to these patterns that are tentatively tried on for size."

Because of the personal individuality of constructs he later calls them *personal constructs*.

The similarity between Kelly's personal constructs and the account of concepts and schemata presented earlier becomes immediately obvious.

The Nature of Personal Constructs

"A construct is a *way* in which some things are construed as being *alike* and yet *different* from others." (Kelly, 1963, p. 105, my italics) A construct, therefore, is a *way*

of *understanding* in terms of the likenesses and differences between things. Furthermore, it is "…just as pertinent to some of the things which are seen as different as it is to the things which are seen as alike." (Ibid, p. 105)

Kelly, (1963, p. 106) talks about the "bipolar nature of constructs" and explains that a black/white construct, for instance, will be the way in which a person views things in a black or white perspective. All things white are seen as the same, but different to black things in terms of this construct. The construct does not apply to all things, it has a range of applicability, and neither do all things only afford one construct, e.g., the black/white, writing/wrapping paper contains two constructs, both applicable to the paper, in order to anticipate the uses for the paper. Note that in this case the paper, called the *element* by Kelly, becomes an integral part of both the constructs.

The two poles of a construct are not opposites in the conventional sense. The other pole of a construct of which the one pole is happy, could be sad, unhappy or mournful, depending on the element under consideration. "The relationship between the two poles of a construct…" should rather be seen as one of "…contrast." (Kelly, 1963, p. 137)

Elements

Kelly's explicit definition of elements: "The things or events which are abstracted by a construct are called elements" (Kelly, 1963, p. 137), is rather obscure. A dictionary, prevalent in America at the time when Kelly was writing, gives the meaning of "abstract", *inter alia*, as "extract to concentrate on". (Funk & Wagnalls, 1946, p. 7).

Elements are therefore the things, or events, that the construct concentrates on at the time. The things or events which form part of the construct in a particular occurrence. Jankowicz (2004, p. 29) notes that "(a)nything can be an element: people, places, institutions, … the list is endless…", although he cautions against "…words and phrases which have clear opposites, or words which represent qualities rather than actions or things."

Construct Elicitation and the Repertory Grid

George Kelly (1991/1955) provided a method which can be used to elicit a person's constructs about certain elements and analyse them. It is essentially a grid with the elements listed in the columns and the constructs, which were elicited from the person who is being interviewed, in the rows. See figure 1. Kelly (1991/1955) called this a *repertory grid*, or *rep grid* for short. It is still referred to as the repertory grid today and although Kelly used it in a clinical psychological situation, it has subsequently been used in analyses of topics as diverse as business management, teaching, drug abuse and the development of chess expertise. (Fransella et al, 2004: Jankowicz, 2004)

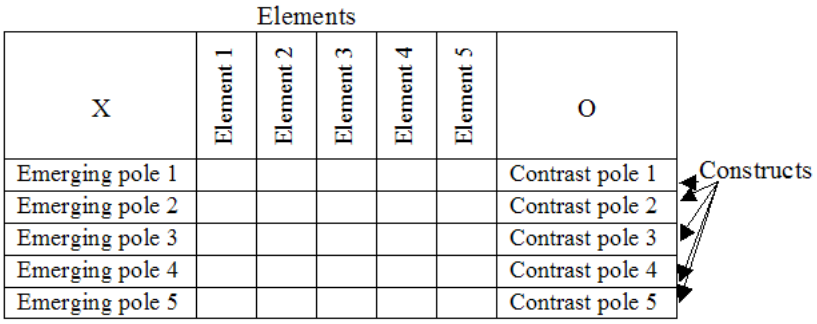

Figure 1: Format for the repertory grid

The elements of the grid may be obtained from the interviewee, or given by the interviewer. (Jancowicz, 2004; Fransella et al, 2004). Elements are features, people or other entities characteristic of a certain topic. (Jankowicz, 2004)

The constructs are normally elicited from the interviewee, but can be supplied in certain circumstances, when the interviewer is working with groups. (Fransella et al, 2004)

The method for construct elicitation, advocated by Kelly (1991/1955), is quite unique and very much the standard procedure for obtaining constructs, even when working in groups. It consists of taking the elements three at a time and then asking the interviewee which two elements he or she considers to be alike in some way and different from the third. The likeness supplies the first pole of the construct, while the difference supplies the contrasting pole. The likeness pole is called the *emerging* pole. (Kelly, 1991/1955; Jankowicz, 2004) The process is repeated with three different elements, until enough constructs have been elicited.

After compilation of the grid, the interviewee then rates each element against each construct. The idea is to decide which side of the construct applies to each element. The corresponding grid cell is then annotated with the appropriate sign for that side. In the case of figure 1, it would be either “X” or “O”. The elements can also be rated against each construct on a scale of one to five, or one to nine, for a more complex analysis. In that case, if the emerging pole fully applies to the element, the rating would be one and if the contrasting pole applies fully, five or nine. In case both poles apply equally, the rating would be three, or five. Thus the elements are ranked on the scale of applicability to each pole of the construct. (Jankowicz, 2004; Kelly, 1999/1955)

Analysis of the grid happens in two ways: Firstly the similarities and differences between elements are isolated. Those are the elements that are rated very similarly or very differently on all the constructs. This gives an indication of which elements are seen in the same way by the interviewee. Secondly, similarities and differences between constructs are isolated for each element. This gives an indication of how the elements are seen as similar or different.

Together the two analysis procedures give a summary of the interviewee's construct system with regard to the particular topic of investigation. (Jankowicz, 2004)

The above is a very short description of the process, which, of course, contains many refinements and techniques designed to understand the interviewee's construct system and how he or she construes the particular topic that is the object of the research.

A RESEARCH STRATEGY

According to Lakoff and Johnson (1999) basic level schemata can be metaphorically imposed on situations. A container schema can be applied literally, for instance, to a physical container like a box, or it can be applied, in a primary metaphor, to an ingredient of a substance, for instance, "there are chillies *in* the sauce".

It is the applicability of basic spatial schemata to primary metaphors that provides a handle for identifying how, or in which way, they are understood. In Kelly's (1955/1991) words: "The simplest, and probably the most…useful type of approach to a person's personal constructs, is to ask him to tell us what they are." (p. 139)

Although the person may not be able to identify the basic spatial concepts, he or she may be able to, if the theory holds and the concept is given to him or her, construct a conceptual basic metaphor with the concept. It is hypothesised that the nature of the metaphor, moderated by the linguistic signs used, will be an indication of the person's construal of the basic concept. His "…transparent patterns or templets which he creates and then attempts to fit over the realities of which the world is composed." (Kelly, 1963, p. 8)

Although this is not a clear-cut construct, it is argued that it is a measure of the way in which the person understands the concept. It is eliciting a construct in reverse, so to speak.

The likenesses and differences between the understanding of the different basic spatial concepts can be isolated and compared to the way in which another person understands it. In short, it is argued that the constructed basic conceptual metaphor can be treated as a construct in the Kellyan sense.

In that light, the research follows exactly the pattern of Kelly's (1955/1991) repertory grid analysis. The interviewee is presented with three basic level spatial concepts and asked how, metaphorically, two of them are the same and different from the third.

For example, in one pilot study, the interviewee was presented with the concepts *movement, displacement* and *direction*. The response was: "Movement and displacement are similar, because I can say 'I am moving right along in my studies, I am much further than I was at the beginning of the semester', whereas direction is more

like ‘I am studying Geography.’” For the grid interview the emerging pole of the construct were formulated as “learning is a path” and the contrasting pole as “learning is a category” with the agreement of the interviewee.

Subsequent analysis showed that the interviewee construed the concepts *position relative to a source and goal* and *forward and backward* as very similar, in terms of the learning metaphor, and *horizontal and vertical* as very different from both.

The interpretation of this observation can be that, due to the linguistic expressive devices the interviewee habitually uses to express spatial concepts, a certain conflation between the source-path-goal schema and schemata related to bodily projection might occur. On the other hand, the interviewee might not be able to relate the concepts horizontal and vertical to movement at all.

This, of course, is conjecture and the topic of further research, but if it turns out to be so, it has definite implications for his or her interpretation of certain representations of space and spatial reasoning which makes use of higher order conceptual metaphors, built from the basic level metaphors. It also has definite implications for the teaching of those representations of space and spatial reasoning.

Results

At the time of writing the research has not been completed, but preliminary pilot studies have shown that it is possible to infer a person’s construal of the basic spatial concepts from the metaphors that that person can construct from the basic concepts.

The study needs to be extended to a sufficiently large sample so that correlations between individual constructions can be drawn in order to test the consistency of the theory.

CONCLUSION

Arguing from basic definitions of concepts and schemata and by lifting out the similarities between those and Kelly’s theory of personal constructs, a method for research into peoples’ construal of basic spatial concepts was designed with the aid of Lakoff and Johnson’s theory of conceptual metaphors.

Preliminary pilot studies have shown that the method may be viable for inferring the nature of a person’s construction, and therefore understanding, of basic spatial concepts.

In order for the research to be useful, it has to be extended to include the building of higher level conceptual metaphors, given the understanding of the basic spatial concepts. It needs to look further into the subsequent interpretation of the traditional

representations of space and spatial reasoning and the implications for learning and teaching spatial representation and reasoning.

REFERENCES

CHANDLER, D. 2002. *Semiotics for Beginners.* http://www.aber.ac.uk/media/Documents/S4B/sem02.html (23 June 2009)

COMMITTEE ON SUPPORT FOR THINKING SPATIALLY. 2006. *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum*, Washington DC., National Academies Press.

EMBREE, MARLOWE C. 2009. *PSY 202 - Introductory Psychology*. University of Wisconsin. http://www.uwmc.uwc.edu/psychology/unit_9_summer.htm (28 Jul 2009)

FOLEY, WILLIAM, A. 1997. *Anthropological Linguistics: An Introduction.* Oxford, Blackwell Publishers.

FRANSELLA, F., R. BELL & D. BANNISTER. 2004. *A Manual for Repertory Grid Technique (2nd Ed.)* Chichester, John Wiley and Sons.

FUNK & WAGNALLS, 1946. *College Standard Dictionary*. New York, Funk and Wagnalls Company.

HUTCHINS, E. 1983. Understanding Micronesian Navigation, in *Mental Models*, In D. Gentner & A. L. Stevens, (Eds), (p. 191-225), Hillsdale, NJ., Lawrence Erlbaum Associates. Retrieved December 5, 2008, from Questia database: http://www.questia.com/PM.qst?a=o&d=55455552

ISHIKAWA,T. & KASTENS K.A. 2005. Why students have trouble with maps and other spatial representations. *Journal of Geoscience Education* 53(2), p.184-187. http://www.nagt.org/nagt/jge/abstracts/mar05.html (23 June 2009)

JANKOWICZ, D. 2004. *The Easy Guide to Repertory Grids.* West Sussex, Wiley.

KELLY, G. A. 1963. *A Theory of Personality: The Psychology of Personal Constructs.* New York, W.W. Norton & Company.

KELLY, G. A. 1991/1955. *The Psychology of Personal Constructs Vol. 1*. London, Routledge.

KING, HELEN. 2006. *Understanding spatial literacy: cognitive and curriculum perspectives.* Planet, December 2006, Issue 17, p.26 – 28. University of Plymouth. GEES Subject Centre. http://www.gees.ac.uk/planet/p17/hk.pdf (23 June 2009)

LAKOFF, G. & JOHNSON, M. 1980/2003. *Metaphors We Live By*. Chicago, University of Chicago Press.

LAKOFF, G. & JOHNSON, M. 1999. *Philosophy in the Flesh: The Embodied Mind and its Challenge to Western Thought.* New York. Basic Books.

LAKOFF, G. & NÚÑEZ, R. E. 2000. *Where Mathematics Comes From*. New York. Basic Books.

LINN, M. & PETERSEN A. C. 1985. Emergence and characterization of sex differences in spatial ability: A meta-analysis, *Child Development* 56, p.1479-1498.

MACEACHREN, ALAN M. 1995. *How Maps Work: Representation, Visualisation and Design*, New York, The Guildford Press.

PEIRCE, C. S. 1931-58. *Collected Writings* (8 Vols.). Ed. Charles Hartshorne, Paul Weiss & Arthur W Burks. Cambridge, MA: Harvard University Press

PEUQUET, D. J. 2002. *Representations of Space and Time.* New York. The Guilford Press.

SCIENCE EDUCATION RESOURCE CENTER. 2008. Carlton College, Northfield, MN http://serc.carleton.edu/research_on_learning/synthesis/spatial.html (1/10/2008)

THORNDYKE, P. 1984. *Applications of Schema Theory in Cognitive Research*. In J. Anderson and S. Kosslyn (Eds.), *Tutorials in Learning and Memory: Essays in Honor of Gordon Bower* (pp. 167–192). San Francisco. Freeman.

VON GLASERSFELD, E. 1995. *Radical Constructivism: A Way of Knowing and Learning*. London. The Falmer Press.