# LINGUISTIC INTERCOURSE WITH SPATIAL PERCEPTION

# COMPARATIVE ANALYSIS IN PRIMARY SCHOOL, INFANT SCHOOL AND THE FAMILY

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*A lot of mathematical abilities as well as general cognitive abilities have come to be understood in the context of spatial perception. According to Newcombe and Huttenlocher (2006), a key aspect of improving spatial-geometrical ability lies in the linguistic coding of space – yet this linguistic intercourse with spatial perception remains unfulfilled. Research in the field of mathematics education indicates that this can be explained by a tendency to interpret situations in arithmetical terms, or to employ more deictically characterised, implicit forms of mediation. The following paper presents a video-based empirical study currently being carried out, which attempts to reconstruct and compare linguistic intercourse with spatial perception in different places children learn – in infant school, primary school, and the family.*

## THEORETICAL BACKGROUND AND RESEARCH FOCUS

### The significance of perceptions of space in the learning of mathematics

The spatial world we live in demands the development of spatial perception. Almost every action of individuals takes place in the spatial world, and consequently cognitive or mathematical abilities are increasingly being understood in the context of spatial thinking. Here it is important to note that broad competency in spatial thinking early in life not only has positive effects on a child's later capacities for thinking in spatial terms, but also on proficiency in other areas of mathematics (cf. Lüthje 2010, p. 17; Stern, Felbrich & Schneider 2006). Grüßing (2002, 2005) and others have made observations that support the assumption that there is a positive correlation between spatial perception and mathematical achievement.

> "Spatial thinking is an essential human ability that contributes to mathematical ability. […] Further, mathematics achievement is related to spatial abilities […]." (Clements & Sarama 2011, p. 134)

These observations are supported by a similar negative correlation. Several studies have reached the conclusion that a lack of ability in spatial perception is linked to dyscalculia, and vice versa (cf. Eichler, Eipert 2005; Grüßling 2005; Maier, P. H. 1999). Spatial perceptions also determine thought and language. "Spatial" concepts are used in many of our everyday metaphors, for example "high-spirited", "on top of the world", "to take up a lot of space". Language is seeking here to describe abstract situations or feelings by using concrete concepts from the world of spatial perception (cf. Fthenakis et al. 2009, p. 77; also cf. Lakoff & Johnson 1980).

Spatial ability is thus essential for children's development. Little attention is paid however to spatial-geometrical content in German schools. An inadequate system and an underestimation of its importance seem to have led to an aversion to the theme in the teaching community. For a long time, German geometry teaching focused almost exclusively on the study of form, and on looking at the world from a two-dimensional perspective (cf. Winter 1976, p. 15; Lüthje 2010, p. 18 f.). Consequently, a number of authors, for example Maier, have criticised modern geometry teaching:

> "Spatial geometry is, as a rule, the learning of vocabulary, arithmetic and algebra." (Maier, 1999, p. 8, translated by the author.)

Authors like Maier have demanded a restructuring of the current primary school curriculum that will make nurturing spatial perception a specific goal of geometry teaching (cf. Maier, 1999, p. 9). If we take the importance of focusing on ability in spatial perception in the development of children seriously, according to Fthenakis et al. (2009, p. 28f.) we have to ask the question: what are the requirements for teaching it in the places children learn?

Henceforth we shall consider that the development of spatial-geometrical perception does not begin in primary school, but far earlier, in the family and in infant school (cf. Acer 2011) and that "Effective learning depends on the support given to all those places where children learn and develop" (Fthenakis et al. 2009, p. 38 f., translated by the author). Clements and Sarama (2011) have observed that, at earlier stages of children's education too, little or no time is devoted to geometry and spatial perception. They suggest failures in teacher training as a possible cause for this (cf. Clements & Sarama, 2011).

**Language and the learning of mathematics**

It is a fundamental goal of mathematics education to enable children to understand and experience the world with the help of a mathematical perspective. Since many mathematical objects and areas are represented in language, it is also a question of developing linguistic abilities that are linked to mathematics. In a number of approaches to mathematics education, language and communicative competence are accorded particular importance with regard to learning. Above all in primary school, according to Maier, H. (2006) teachers often attempt to introduce concepts through visualisations with the help of illustrative models; that is to say, the form of "iconic" representations (on these concepts see Bruner 1971). According to Maier, there is an inherent problem here, because these visual techniques do not allow a comprehensive understanding of mathematical concepts. This is true above all because, as Maier, H. (1986) has it, mathematical objects are abstract, and it is therefore difficult to access these objects sensually through enactive and iconic visualisations. He suggests that this dilemma can only be resolved through the use of language and symbols, underlining the importance of language in the learning of mathematics:

> “As fundamentally abstract concepts, [mathematical concepts] can only be legitimately handled and represented on a linguistic-symbolic level” (ibid. p. 137, translated by the author).

According to Maier (1986, 2006), intensive verbal communication is therefore an indispensable educational tool when introducing new mathematical concepts. Pimm (1987) goes one step further, and considers mathematics as a social activity that is structurally closely linked to verbal communication. From this standpoint he uses the metaphor “Mathematics is a language?” (ibid. p. XiV) to raise the question of whether mathematics may be considered as, if not a natural language, a unique style of language. His concern here is to structure the concept of mathematics partly in linguistic categories, with the principal goal of rendering the teaching and learning of mathematics easier to explain (cf. ibid. p. XiV f.).

Returning to the area of geometry in the light of this idea, it is worth referring to Newcombe and Huttenlocher (2006), who have remarked that the linguistic coding of space is a central competency with relation to spatial thinking. Although the academic literature places great importance on linguistic intercourse with mathematics, particularly with relation to spatial perception, so far we have noted the following: in German schools, spatial-geometrical content barely appears to feature, whilst outside of school in the family a linguistic intercourse with space is frequently neglected. At the time of writing the author is unaware of any experiments that have been carried out on spatial perception in German infant schools.

**Support in learning situations containing an element of mathematics**

In infant school, primary school and in the family, children are involved in processes of negotiation of meaning through which they become increasingly familiar with mathematical content. These processes can be interpreted, with Tiedemann (2012), as “support”. With this concept Tiedemann draws a link to Bruner’s (1983) concept of a support system whereby children are involved in repeating models of interaction, which leads to their becoming increasingly autonomous actors in their cultural environment. A crucial point here is that support can be understood as an interactional phenomenon produced by adult and child together. Whilst the adult assists, the child orients the adult’s utterances and actions by his or her reactions in the situation of negotiation of meaning. Tiedemann (2012) adapts this approach for mother-child mathematical discourses, and reconstructs different aspects and methods of support. Therefore, linguistic intercourse with spatial perception in primary school, infant school and the family as described in this study can be reconstructed and understood as “support”. One can therefore formulate the question: in the three different places of learning, which forms of support can be observed in processes of negotiation of meaning relating to spatial perception?

## Research gap and focus of the study

Anderson (1997) investigated the parent-child interaction of 21 four-year-old children and their parents in situations containing an element of mathematics. An incidental result of her study is relevant to the present paper. In Anderson's study families were given multilink blocks, a child's book, blank paper, and preschool worksheets, and a fifteen-minute audio recording was made of each family as they began to try and solve the puzzles. Anderson was able to discover that the parent-child interaction included a wide range of mathematical approaches of various levels of sophistication, showing counting as the core mathematical skill. Interestingly however, she was unable to find virtually any explicit verbalisation of spatial description in the interaction between parent and child. This leads me to suppose that these verbalisations of spatial descriptions were compensated for or replaced by deictic gestures in order to resolve the situation.

In relation to recent research on indicative gesture, the most important works in English include above all Alibali (2005), Alibali and Nathan (2007) and Hostetter et al. (2006). Following these authors, gesture can be differentiated to support both teacher behaviour and interaction with spatial perception. Alibali und Nathan (2007) emphasise that gesture is a means of communication which can be employed by teachers, like language, to support the understanding of their pupils. Therefore, on the one hand gesture can be used to clarify something that has already been portrayed in language. On the other hand according to Alibali (2005) deictic gesture is used to convey precisely such information that has not been linguistically expressed.

From an educational theoretical perspective, this fact seems to contain a crucial problem. According to Maier (2006), quoted above, approaches to mathematics which focus on the senses are problematic because mathematical objects are abstract, and it is therefore difficult to access them sensually through visualisations. A deictically characterised form of support however lends itself to precisely the visual approaches which, according to Maier, cannot communicate mathematical concepts.

If we take "learning" to be a process of dialogue, which may only be described in the course of coordinating the mental activities of at least two individuals, and whose components, in the sense of genetic interactionism (cf. Miller 1986, p. 15 ff.), are anchored in the activities of the collective, all participants in the dialogue must adapt and re-adapt their interpretations of situations in order for processes of negotiation of meaning to successfully make progress. Usually only a small functional adaptation of individual interpretations is required from the participants in the dialogue in order to move the interaction forward. This kind of temporary adaptation of meaning is called "working consensus" (Krummheuer 1992, p. 25; on the concept of "working consensus" see Goffman 1959, p. 9 f.). According to Krummheuer and Brandt, learning can be understood in this light as the increasingly active participation in these asymmetrical processes of the negotiation of meaning, so that the conditions of autonomy of the adult can be translated to the children. The question is now, whether this kind of short-term working consensus and opportunities for learning through gaining autonomy can still be realistic goals if, during negotiation of meaning in an asymmetrical interaction situation, aspects of mathematical issues are expressed by the adult through deictic gesture instead of language. These gestures could result in a vague situation where the subject of negotiation is often implicitly obscured, and where the children are barely given any opportunity for more active participation (cf. "Implizite Pädagogik" Schütte 2009, p. 191 ff. or "Implicit Pedagogy" Schütte & Kaiser 2011, p. 247 ff.).

However, even when learning is anchored in the mental constitution of the individual, and the individual participants are accorded every decisive mechanism and process in Piaget's sense of genetic individualism (cf. Miller 1986, pp. 15 ff.), a further problem nevertheless emerges. If language is understood in this way, most learning does not take place in processes of negotiation of meaning between participants in a dialogue: instead, learning processes are portrayed by the individual constructs of the individual participants. Not only do processes of negotiation of meaning remain vague, as Maier, H. suggests (2006), when certain aspects are not linguistically expressed: opportunities to access processes for creating mental constructs can be hampered and restricted, since deictic gesture is very far from being unambiguous or self-explanatory. In addition, it can be concluded with Huttenlocher and Newcombe (2006) that the use by adults of deictic gesture as a substitute for vocalisation will give children less opportunity to learn the linguistic coding of space.

In some mathematical topics gesture plays an especially large role in teaching. Unlike in other mathematical areas, in these situations negotiation on spatial information seems to demand the use of gesture (cf. ibid. 2005, p. 310 ff). Conclusions drawn by Acar (2011) also point towards a neglect of spatial perception in everyday family interaction. Looking at various play-situations, Acar shows that parents approach building games – which belong in the realm of spatial perception from a mathematical point of view – in such a way as to make them exercises in arithmetic, focusing the support they give to the child on counting the wooden blocks whilst spatial-geometrical application remains lacking.

**Aim of study**

The present study aims to closer examine the validity of the conclusions mentioned above, and extend them to apply to all three places of learning. According to Hostetter et al. (2006), the gestures of teachers are not only habitual and in this context tend to be conscious; therefore they do not escape alteration. From this perspective teachers are very much capable of actively influencing the gestures they produce. They can decide to increase their use of gesture or to stop using gesture altogether. Using this idea, the present study aims to establish how parents and educators, as well as teachers in school, construct the learning of spatial-geometrical mathematical content in linguistic terms. It also aims to identify and reconstruct any differences in this respect that exist between the different places of learning. The long-term goal of the study is to identify opportunities and risks through an integrated examination of linguistic intercourse with spatial perception, and to use this information to develop a training concept to support parents and infant and primary school teachers in the fostering of spatial thinking. The research question is the following: Which kinds of linguistic intercourse with spatial perception can be reconstructed in the three distinct places of learning: family, infant school, and primary school?

## METHODOLOGY AND METHODICAL PROCEDURE

### Methodological considerations

The investigation that forms the basis for this study is qualitatively oriented and belongs in the field of interpretive education research, both in and outside a school environment; more precisely, it represents an interactionistic approach of interpretive classroom research in the field of mathematics education (cf. among others Tiedemann 2012, p. 68; Schütte 2009, p. 78 ff.). Video recordings form the empirical basis for the study. The research questions will be adapted according to an innovation in perspectives. The research will simultaneously look at children of similar ages (5-7 years) in primary school, infant school and in families. A comparison of different places of learning takes all kinds of development in children into account, and at the same time gives a comprehensive base for proposals regarding the development of spatial thinking. With reference to Soeffner (1989, p. 25 f.), it is assumed that the individuals under observation, in view and in spite of the potentially new situation (study materials, camera, etc.), nevertheless resort to routines of behaviour and interaction that they have previously found to be successful. On this basis the observed situations are taken to represent the everyday in the schools, infant schools and families studied (cf. also Tiedemann 2012, p. 64 ff.; Schütte 2009, p. 72 ff.). In this sense the study at the base of the present paper attempts to align itself with the general goal of educational research, or research in general – to initiate, with scientific evidence, a shift in the focus of research, or at least to reveal possibilities for change in this respect. Krummheuer and Naujok (1999) demand, for example: "[...] the theoretical products should identify conditions under which teaching can be altered" (ibid. p. 24). The present paper too attempts to achieve this goal, making use of more recent interpretive research studies in mathematics education; it also attempts to discover possibilities for altering behaviour in adults that may be habitual and is not rationalised by the presence of a fixed aim, in order to establish the conditions to accomplish these changes.

### Method of data collection

The following gives a short overview of the data collection methods in the individual places of learning. The study is planned as a cross-sectional video-study. Data are collected in infant and primary schools as well as the respective families of the infant and primary school pupils. Data began to be collected from the infant school and the families of the infant school pupils in June 2012. This process is now complete, and data collection from the primary school and the families of the primary school pupils is currently underway. Data collection will be completed during October 2012, so that data evaluation can start from November 2012. In the infant school, on two respective visits two different play and discovery exercises were carried out with one teacher and two children. Similar play and discovery exercises were carried out, also over two visitis, in the families of the children. In the families the situations were played out with a parent and the respective children; in the primary school, however, the procedure was different, since the children are taught and looked after by pedagogical experts with mathematical didactical expertise. This meant everyday teaching was investigated in relation to the central ideas of space and form. Teachers were merely given thematic areas – for example building blocks – around which to independently plan and deliver a lesson, without any further external input. The families of the primary school pupils were given tasks fundamentally similar to those given to the families of the infant school pupils, only adapted to suit the older age-group.

In the present study the characterisation of specific components of spatial perception is based on a model by Maier, P. H. (1999, 2001), which is founded on five components of spatial perception: (1) spatial perception, (2) visualisation, (3) mental rotation, (4) spatial relations and (5) spatial orientation (cf. Maier, P. H. 2001, p. 71 f.). On the one hand these five components can be categorised such that the "outside position" refers to the participants in the dialogue; that is, whether an "inside" or "outside" position is adopted. On the other hand, we can differentiate between "static" and "dynamic" mental processes (cf. Maier, P. H. 2001, p. 72).

Every play and discovery situation was divided up into three tasks. The first situation could be categorised a "building" situation, and was developed on the model of the spatial geometrical game "PotzKlotz"1. The skills demanded were, using Maier's (2001) spatial geometrical areas, spatial relations, mental rotation and visualisation. The thematic focuses of the three parts of the exercise given in the infant school and in the families of the infant school pupils were as follows: (1) Working together to build a copy of a model, (2) Building from instruction, (3) Building a model and then reconstructing it. For the families of the primary school pupils the focus was very slightly different: (1) Building from instruction, (2) Building a model and reconstructing it, (3) Comparing buildings.

In order to give some insight into these play and discovery situations, the task (2) Building from instruction for the families of the infant school pupils is shown below as an example.

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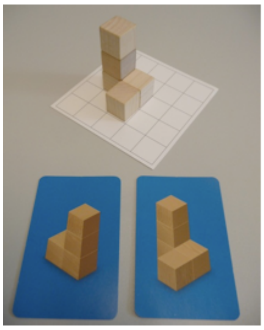
[1] Spiegel, H. & Spiegel, J.

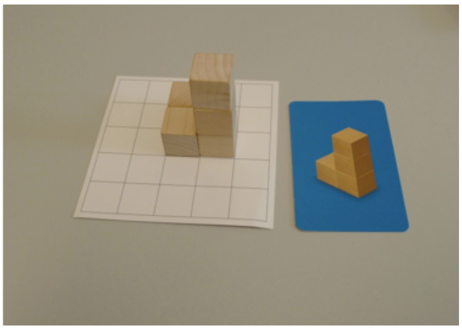
**PotzKlotz – Build what I say!** 2 Players

You need a pack of building cards placed face down, and 5 building blocks.

Task:

The first player draws a building card without letting the second player see what is on the front. The second player has five building blocks. The first player directs the second player in building the structure that is on his or her card. When the building is finished, look at the card together and compare the building to the picture. Then change round, and continue until each player has given instructions for two buildings.





The second play and discovery situation can broadly be understood as an adaptation of Piaget and Inhelder's "Three Mountains" test (1971, p. 251)2. In terms of Maier's (2001) spatial geometrical areas, the situation demands skills in the area of spatial orientation. For this situation too, three tasks were developed for each group. In the infant school and the families of the infant school children the exercise used a Lego-Duplo® zoo, whilst in the families of the primary school children a Lego® pirate ship was used. The three focuses of the situation for infant school and infant school families were as follows: (1) Reconstructing a building from a photograph, (2) Orientation from a given position, (3) Finding positions from a given orientation.

Once again the second task for the families of the infant school children is portrayed below as an example.

[2] cf. Grüßing, M. (2002): Wieviel Raumvorstellung braucht man für Raumvorstellungsaufgaben? In: ZDM 2002 Vol.34 (2), p. 40f.

**Zoo – What can Emma and her Mum see?** 2 Players

First you need to set up the zoo.

Task:

Imagine your Duplo zoo were a real zoo. Emma and her Mum have gone for a walk to see the animals. You can see 3 people in the zoo (the little girl, her Mum and the zookeeper). What can Emma, her Mum and the zookeeper see from their positions in the zoo (they can turn round, too)? Which animals can they see, and where exactly are these animals?

### Methods of Data analysis

In the analysis of the interaction units in the video-recorded situations we have aligned ourselves with a reconstructive-interpretive methodology and a central element of the "Grounded Theory" research method, namely the methodical approach of comparative analysis (cf. among others Strauss & Corbin 1996). In the analysis of the linguistic intercourse with spatial perception, video sequences are analysed with the help of interactional analysis (see for example Krummheuer 2010). The interactional analysis allows us to reconstruct the constitution of negotiations of meaning in interaction between individuals (cf. modifications by Schütte 2009). In order to reconstruct additional common structural features in the linguistic intercourse with spatial perception in the different institutions and with different adults, the video-recorded situations are systematically compared using the "Comparative Analysis" method (cf. ibid).

## RESULTS

The study has been running since January and the data collection phase is currently being concluded. The goal is to be able to present a first analysis with examples from the three institutions for discussion at the conference.

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