KINDERGARTNERS’ USE OF GESTURES IN THE GENERATION AND COMMUNICATION OF SPATIAL THINKING

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Recent studies have advocated that mathematical meaning is mediated by gestures. This study explores how kindergartners use gestures in a semiotic transformation activity involving the description of spatial relationships between objects. The two 5-year-old children that participated in the study used gestures throughout the whole activity, mainly iconic gestures (representing images of objects) and gestures combining iconic and deictic (locating objects in space) properties. A multidimensional linkage between children’s gestures and speech, as well as, a significant effect of the teacher’s gestures on one child’s gestures were found. Findings showed that gestures are essential in the construction and communication of early mathematical meaning and raise important questions for future research.

Keywords: gestures, kindergartners, spatial thinking, semiotic transformation

INTRODUCTION

The semiotic approach to the learning and teaching of mathematics constitutes a very important trend in the research field of Mathematics Education (e.g. Gagatsis, 2003; Presmeg, 2006). A new trend of this research area concentrates on the examination of bodily movement and particularly on gestures. In the last years gestures and bodily movement have been considered as a source of information and a contributor in mathematical thinking and communication (Edwards, 2009).

The study of gesture is still a young research field within mathematics education and many theoretical and methodological questions remain open (Radford, 2009). Existing research in the mathematical domain has focused on the role of gestures in the emergence of mathematical thinking by students in primary, secondary and higher education levels (e.g. Edwards, 2009; Radford, Bardini, & Sabena (2007); Roth & Thom, 2009). To our knowledge, the gestural activity of preschool and kindergarten children in relation to thinking and communicating about mathematics has not been addressed to a great extent yet. In this paper we analyze gestures as a semiotic resource used by kindergartners into the learning process of mathematics and specifically in a semiotic transformation task of spatial character, involving the conversion of a visual spatial array into verbal description.
THEORETICAL FRAMEWORK

Semiotic representations and gestures in mathematics education

Mathematics education includes a wealth of ideas and concepts and constitutes an area of human activity and thinking, which is characterized by the use of multiple representations. A representation is considered as any configuration of characters, images or concrete objects that stand for something else (e.g. Elia, Gagatsis & Demetriou, 2007). Gagatsis, Michaelidou and Shiakalli (2001) support that the advancement of mathematical knowledge is accompanied by the creation and development of new semiotic systems of representation that coexist and operate simultaneously with the first and basic system, that of natural language.

Representations are often concerned as connected with a sign. Saussure defined the sign as a combination of two mental constructs, roughly translated as a “signified” together with its “signifier” (Presmeg, 2006). Within this wide conception of sign Arzarello, Paola, Robutti and Sabena (2009) regard gestures as an important semiotic resource related with the more traditional signs (such as spoken or written language, mathematics symbols, and so on).

Gestures are defined as spontaneous movements of the arms and hands, closely synchronized with the flow of speech (McNeill, 1992). Parrill and Sweetser (2004) define the meaning of a gesture as “the relationship between how the hands move in producing a gesture, and whatever mental representation underlies it, as inferred both from the gesture and the accompanying speech” (p. 197). McNeill (1992) proposes five dimensions of gestures with respect to their meaning: 1) deictic gestures (locating existing or virtual objects and actions in space with respect to a reference point), 2) metaphoric gestures (presenting an image of an abstract object or idea), 3) iconic gestures (standing for images of concrete entities and actions), 4) temporal highlighting gestures (simple repeated gestures used for emphasis) and 5) gestures that modulate social interactivity.

The role of gestures in mathematical thinking

Mathematical cognition is not only mediated by written symbols, but is also mediated, by actions, gestures and other types of signs (Radford, 2009). Particularly, children’s semiotic activity in mathematics includes action, gestures and speech. When mathematics is seen as an embodied, socially constructed human product, gestures constitute a particular modality of embodied cognition (Edwards, 2009).

Roth and Thom (2009) claim that gestures are genuine constituents of thinking. Radford (2009) describes gestures as the very texture of thinking and as important sources of abstract thinking. Gestures, along with speech and inscriptions, jointly support the thinking processes of students (Arzarello et al., 2009). When a better understanding occurs, actions become shorter and gestures and language become more relevant (Radford, 2009). McNeill (1992) noted that, “Speech and gesture are elements of a single integrated process of utterance formation in which there is a synthesis of opposite modes of thought” (p. 35).
Gestures can be fundamental for the effectiveness of mathematical communication (Roth, 2001), as well. Along with oral speech and written inscriptions (drawings and graphing), gestures can serve as a window on how learners think and talk about mathematics (Edwards, 2009) and on inner thoughts or as conveyors of ideas that are already somewhere in the mind awaiting the proper material, namely, verbal expression (Radford, 2009).

**Spatial thinking in early childhood mathematics**

Geometry and spatial thinking are very important areas of mathematics learning in all educational levels, including early childhood education (Sarama & Clements, 2009). They involve grasping the space in which the children live and move (Freudenthal, in NCTM, 1989). A major spatial competence is spatial orientation, which involves the understanding and operating on relationships between various positions in space (Sarama & Clements, 2009).

Mathematical understanding and, in terms of this study, understanding of spatial concepts and relationships evolves through the transformation of semiotic representations. This is because different types of representation provide information about different aspects of the concept, and therefore switching from one representation to another makes explicit various attributes or aspects of the same concept (Duval, 2006). Thus, as children link their spatial knowledge to verbal, analytic knowledge, they move beyond visual thinking which is restricted to surface-visual ideas. Connecting spatial representations to language can help children develop the ability to reason and communicate about space and thus gain deeper understanding of spatial concepts and relationships (Sarama & Clements, 2009).

In the present study, a spatial orientation activity is designed and used. This activity requires semiotic transformations, that is, conversions between spatial representations and verbal descriptions.

**Gestures and spatial thinking**

In activities that entail communication about space, besides words, people frequently use gestures (Ehrlich, Levine & Goldin-Meadow, 2006). A number of studies have revealed that gesture and spatial thinking are connected to one another. Krauss (1998) has found that people use gestures more frequently in defining spatial words than non-spatial words. Gestures occur often in people’s descriptions of their navigation in space (Emmorey, Tversky & Taylor, 2000).

Despite the growing evidence about the link between spatial skills and gestures, limited attention has been given on the role of gestures in the development of spatial thinking (Ehrlich et al., 2006). Ehrlich et al. (2006) explored the strategies 5-year-old children used to solve spatial transformation tasks. The findings of the particular study showed that children frequently produced gestures whose meaning was not necessarily expressed in the accompanying speech. Children who referred to spatial information in their gestures but not in their speech were more likely to succeed. These findings suggest that gesture has the potential to improve early spatial skills.
The present study addresses the issue of the role of gestures in young children’s ability to mentally manipulate spatial information, by examining the gestures kindergartners produce in a spatial orientation task that requires describing a spatial array of objects the children constructed themselves to another person (teacher) who could not see it. Specifically, the questions we tackled were the following:

(1) What are the dimensions of the gestures kindergartners produce when carrying out conversions from a spatial representation to verbal description?

(2) What is the relationship between the kindergartners’ gestures and language in carrying out a conversion from a spatial representation to verbal description?

(3) What is the effect of the teacher’s gestures on the kindergartners’ gestures in the conversion activity?

METHOD

The participants were two five-year-old kindergartners from a private kindergarten in Nicosia, Cyprus. In this study we will refer to the two children as child 1 and child 2.

The spatial orientation activity, in which the children were involved, was designed on the basis of a method of the Didactics of Mathematics that refers to the designation of students’ mathematical thinking and focuses on situations of mathematical engagement and communication. According to this method, students solve problems in pairs or in groups, in order to have the chance for oral or written communication between them. This method allows for a precise analysis of students’ answers and a specification of their mathematical ideas (Brousseau, 1997).

Thus, the activity, which had the form of a game, required two players, one of which was a researcher (co-author of the paper). The participating researcher in the activity was the kindergarten teacher of the children. Each player had to use wooden bricks of different shape in order to make a construction. The two players sat opposite each other, having a small wooden wall in the middle, so that each player was not able to see what the other player was constructing. The aim of the activity was the first player to create the same construction with the opposite player, based on the latter’s description. The activity involved three parts (rounds) and was carried out separately for each child. In the first and the third part of the activity the child had to make the construction and describe it to the other player (teacher), while in the second part the teacher was the player that had this role. During the second part, the teacher used the gestures consciously in order to help the child understand her words.

To examine children’s gestures and language, their reactions and utterances during their participation in the activity were video-recorded. Guided by our research questions and theoretical framework, we conducted a data analysis of the two semiotic resources, namely, spoken words and gestures that were used by the children to describe their own constructions. The interplay between the two semiotic resources was analyzed not only synchronically, but also developmentally, over time. To study
the influence of the teacher’s gestures on the children’s gestures, the similarities between the teacher’s and the children’s gestural behavior were explored.

RESULTS
To identify the dimensions of children’s gestures during the activity (Research Question 1), McNeill’s (1992) proposed dimensions of gestures were used. This analysis showed that the meaning of children’s gestures was multidimensional. Many gestures used by both children were of iconic nature. They used the iconic gestures mainly to present the shape of the various bricks they used. An example concerns the shape of cylinder, for which child 1 moved her finger to make a round line vertically in the air (Figure 1a). For the same shape, child 2 used her pointing finger and thumb to form a circle (Figure 1b).

In both children’s gestures we also distinguished a great number of gestures that can be considered as deictic and iconic at the same time. Children used deictic and iconic gestures when speaking of spatial relationships between bricks. For instance, to explain the placement of four bricks in her construction, child 2 used the expression “one on the top, one at the bottom, one on the left and one on the right” moving both her hands to the corresponding positions (deictic property). At the same time she opened her hands to form a flat surface and put them next to one another in a horizontal direction and opposite to one another in a vertical direction, respectively, in order to present the image of the orientation of the parallelepipeds (iconic property) (Figures 1c, 1d).

Figure 1: Iconic gestures for the shape of cylinder by (a) child 1 and (b) child 2; Child’s 2 iconic and deictic gesture (c) for the placement of the parallelepiped at the bottom of the construction in a horizontal direction, (d) for the placement of two parallelepipeds on the left and on the right of the construction in a vertical direction

A small number of gestures were identified as only deictic for both children, who used them to present the location of some bricks with respect to bricks that they already described. For instance, to show the position of a brick, which was on the right side of another brick, child 2 moved her right hand up and down once (Figure 2a). Temporal highlighting gestures were used even less frequently by the children, mainly in trying to emphasize and enforce to the teacher what they were saying. For example, child 2 moved her hands repeatedly one on top of the other tapping them at the same time in order to highlight that three bricks should be put on top of each other
Metaphoric gestures were the most rarely produced. Child 1 was found to use a metaphoric gesture for the concept “small”. As she was explaining to the teacher to “take two circles (meaning cylinders), but small”, for the word “small”, she moved her hands close to her face and formed fists (Figure 2c).

With respect to the connections between language and gestures (Research Question 2), we observed that children were using gestures and language simultaneously. In some cases, the meaning of children’s words and gestures coincided. While the children were trying to explain to the teacher where to place the bricks, they were like holding the brick and placing it in the position they were trying to explain. An example is the verbal expression of child 2 “…take a roof and place it on top” which was accompanied by the gesture shown in Figure 3a.

In other cases children replaced verbal expressions with gestures, in order to explain what they were thinking. When the children tried to describe the position of a brick, they frequently used the expressions “like this (not this)”, “place it... emhhh, place it this way...”, “place it here” and simultaneously produced a gesture to illustrate what they mean. For example, child 1 while trying to explain to the teacher how to place the two “long shapes” (parallelepipeds), she was showing with her hands their position, highlighting that they should be placed “like this” (apart) and “not like this” (not together) (Figures 3b, 3c).

An aspect of the linkage between language and gestures that was examined was how this connection changed over time during the activity. An interesting example is that
in the first part of the activity child 1 opened her hands, one hand to the left and the other to the right side of her body (iconic gesture) to represent the “long shape”, meaning the parallelepiped (Figure 4a). In the third part of the activity, every time child 1 used the particular term, she produced a different iconic gesture consistently. She stretched out one hand vertically to her body and formed a straight line in the air by moving her hand near her chest (Figure 4b). This is explained by the different position of the parallelepiped between the first and the third part of the activity. In the first part of the activity, the brick was in a horizontal position while in the third part it was in a vertical position. However, the last time she referred to this shape, she did not use any gesture. For the same shape, child 2 used consistently a “smaller” iconic gesture than child 1, during the first part of the activity. When talking about the shape (e.g. “take 4 lines”) she moved her pointing finger vertically towards her body to draw a small straight line in the air or on the table (Figure 4c). This gesture was not used in the third part of the activity when child 2 used the verbal expression “line”.

Figure 4: (a) Child’s 1 gestures for the parallelepiped in the first part of the activity, (b) Child’s 1 gestures for the parallelepiped in the third part of the activity, (c) Child’s 2 gestures for the parallelepiped in the first part of the activity

The teacher had an obvious effect in the way child 1 was behaving during the activity (Research Question 3), since she was imitating her expressions and gestures in respective situations. In one case, child 1 even “extended” the teacher’s gesture. Specifically, in the second part of the activity, while the teacher was explaining that two bricks are attached to each other she put the palms of her hands together. In the third part of the activity, when child 1 had to describe the relative position of two bricks and in particular that they should be apart from one another, she used the same gesture and the “opposite” gesture that she observed before from the teacher. In particular, the child first moved her hands away from one another highlighting that they should be placed “like this” (apart from each other) (Figure 3b) and then put the palms of her hands together clarifying that they should not be put in this way (not attached) (Figure 3c). On the contrary, the gesture used by child 2 was not influenced by the teacher’s behavior.

CONCLUSIONS

This study examined the gestures two kindergarten children use while communicating in the context of a semiotic transformation activity which involved spatial orientation
abilities. Children were found to use gestures throughout the whole activity. The most commonly used gestures were the iconic gestures and the gestures that combined iconic and deictic properties. This finding can be attributed to the spatial and geometric nature of the activity which encourages imagistic thinking. Metaphoric and temporal highlighting gestures were rarely used by the children. In contrast to producing iconic and/or concrete deictic gestures, in which children only think about the object or spatial relationship the gesture is representing, producing these types of gestures are cognitively complex, involve meta-cognitive abilities and therefore are developed in later years (McNeill, 1992). Further investigation on how the occurrence of abstract gestures varies in activities of spatial context or other mathematical topics among young children and the associations of this gestural behavior with children’s mathematical achievement and other child characteristics (e.g. age, gender) could be theoretically and practically important.

A close multidimensional relationship between gestures and language was revealed. This relationship appeared in students’ behavior in three distinct ways. Firstly and most frequently, there was a speech-gesture match. Specifically, while describing their constructions, children appeared to produce gestures that represented the information given by their verbal expressions. Secondly, in some cases children replaced language with gestures and thirdly, children’s gestures complemented and enriched their verbal descriptions. The second and third type of the gesture-language relationship reveals a mismatch between gesture and speech, as different information is conveyed by speech and gesture (Arzarello & Edwards, 2005). Although previous research (McNeill, 1992) suggests that by the age of five gestures co-occur with speech, the use of gestures only without the corresponding words, by the children of this study, in some cases, could be explained by a lack of flexible knowledge in the construction of sentences for describing spatial relations. Furthermore, the spatial character of the activity, and the fact that the spatial arrangement the children described had been constructed by themselves and was in front of them, probably endorsed the visual elements rather than the analytic elements of their thinking. As a consequence, gestures were stronger than verbal utterances in some parts of their descriptions.

That some dimensions of the children’s thought, such as the orientation of the shape, were presented in the gesture and others, such as, the form of the shape, were presented in linguistic form, at the same time, provided evidence for the complementary role of gestures to speech. In fact, the children used gestures, words and artifacts (i.e. spatial array of wooden bricks) to make the different properties of geometrical shapes apparent, that is, to objectify mathematical knowledge (Radford, 2009). Each mode of representation made its own contribution to the whole and was essential and valuable in representing children’s spatial thinking. The above suggest that speech, gestures and the semiotic aspects in the perceptual environment (i.e. the spatial array) were in a dialectic relationship and thus they were all involved in the construction of mathematical knowledge (Roth & Lee, 2004). It can be asserted that
gestures along with speech and artifacts may act as semiotic means of objectification in mathematical activities by students not only in primary or secondary education (Radford, 2009), but also in the kindergarten.

A main concern of the study was the role of the teacher’s gestures in the communicative process during the activity. In the specific activity the choice of having each child to start the game, the teacher to follow and then the child to play again, gave us the opportunity to identify the effects of the teacher’s behavior on the children’s behavior. Zooming at the interaction between the teacher and the children during the game, it emerged that only one of the two children was influenced by the teacher’s gestures. This child not only emulated the teacher’s gestures, but added a contrast to the gesture of the teacher. Specifically, the child used a gesture that represented the relative position of two separated bricks in her construction, and then a gesture to show how this position is opposed to the image of two attached bricks (counter-example), which had been previously represented by the teacher’s gesture. According to McNeill (1992) adding contrasts is considered as a mechanism by which gestures can affect thought. Thus, this finding provides further evidence for the important role of gestures in young children’s development of spatial thinking. Evidence is also provided for the influential role of the teacher in the mathematics classroom, as the teacher is often a model for the students, who tend to be affected by her actions and expressions. However, there was not an effect of the teacher’s gestures on the other child’s gestures examined here. This inconsistent finding between the children raises an important question regarding the relationship between mathematics teaching and gestures: What factors influence the extent to which teachers’ gestures affect children’s gestures and their learning outcomes in mathematics instruction? The child characteristics, such as the child’s prior knowledge, the complexity of the learning activities and the characteristics of the teacher’s behavior could be some of the factors that future research may explore.

REFERENCES


