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Mathematizing in preschool: children's participation in geometrical discourse

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ABSTRACT

This study explores preschool children's mathematizing in everyday block play activities. Building on an ethnomethodological and multimodal conversation analytic framework, we explore how geometry (i.e. spatiality, shape, and symmetry) is actualized in children's verbal and embodied interaction with their peers, pedagogues, and material environment. The selected data are drawn from a video ethnographic study in a Swedish preschool in which a boy and a girl play with a magnetic construction toy. The results of the study demonstrate how the participants orient to spatial locations, properties, dimensions, orientations, transformations, and shapes as they build a house. The children are shown to rely upon verbal and embodied resources such as deictics (e.g. here, there, these) and pointing gestures as geometrical aspects are actualized in their interaction. The study contributes with knowledge on preschool children's everyday mathematizing, in particular, children's appropriation of geometric discourse as it emerges in the unfolding flow of interaction.

KEYWORDS

Ethnomethodology/
conversation analysis; block
play; geometry;
mathematizing; preschoolers'
multimodal interaction

Introduction

This study explores children's mathematizing in the block play area, with a particular interest in preschoolers' understandings of spatiality, shape, and symmetry, that is, geometry (see NCTM 2000; Seo 2003). Research about early childhood mathematics is a comprehensive field where children's counting, sorting, numeracy, and development of number sense are often focused (e.g. Baroody, Lai, and Mix 2006; Doverborg and Samuelsson 2000; Edens and Potter 2013). As yet, there are only a few studies that focus on children's development of understandings of geometry (although see e.g. Bäckman 2015; Casey et al. 2008), although there is a growing interest in how block play can contribute to children's early mathematical development (e.g. Albinsson 2016; Ness and Farenga 2007; Ramani et al. 2014). Previous research suggests that block play is of particular importance to children's development of spatial skills and understanding (e.g. Jirout and Newcombe 2015; Trawick-Smith et al. 2016).

To examine how children actively participate in geometrical discourse in everyday interaction in the block play area, we use an ethnomethodological and multimodal conversation analytic perspective (e.g. Goodwin 2000; Goodwin and Goodwin 2004). We analyze

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participation in mathematical discourse, *mathematizing*, as a socially organized process (Sfard 2008), based on video recorded data in which preschool children (aged 5 years) participate together with a pedagogue¹ in a block play activity using a magnetic construction toy in a Swedish preschool. In the analysis, we explore how the participants mobilize a multitude of multimodal resources such as talk, pointing, gesture, body orientation, and material structure in the environment as they make relevant geometrical aspects.

The study thus aims to contribute to research on children's everyday interactions during block play and its relation to development of mathematical understandings, in particular, geometry (cf. Clements 2001; Ness and Farenga 2007).

Research on geometry in block building play

Geometry is a mathematical field concerned with questions of shape, size, the relative position of figures, and the properties of space. Previous research has shown that playing with blocks promotes preschool children's development of understandings of geometry. For example, Casey et al. (2008) examined the effects of structured block building activities and found that block play encouraged children to test spatial relationships while building, in particular, when it was organized within the context of storytelling. The narrative motivated the children to build the structures the way the characters of the story requested, something that in turn contributed to make critical elements of the block building tasks more salient thus increasing the children's understanding of spatiality. Caldera et al. (1999) reported that preschoolers' block building skills appear to be related to their spatial visualization skills as measured by their ability to analyze and reproduce abstract patterns, to abstract a geometric figure embedded within a more complex figure, and to reproduce three-dimensional structures made from cubes. Ferrara et al. (2011) investigated if the context of block play had an impact on the amount of spatial language that children (aged 3–5) and their parents used in joint play sessions. They concluded that guided play contexts, in which the participants were given numbered photographs depicting the steps required to build a specific structure, elicited more spatial language both from parents and children compared with other play contexts (e.g. free play). Ramani et al. (2014) observed preschoolers aged 4–5 years building houses together with a peer in a guided block play activity. They found that children's spatial talk was intertwined with talk about features of the house that the children imagined they were building. The findings suggest that playing with peers may help children develop and expand their spatial understanding as they engage in spatial talk while building. In all, these studies indicate that there is a relationship between block building play and children's development of spatial understandings. However, they are all conducted with an experimental design in the shape of interventions and guided play activities, sometimes accompanied by pre- and post-tests of children's spatial skills and understandings.

In contrast, some studies argue the importance of studying children's everyday interactions. Based on case studies, Ness and Farenga (2007) show how children develop geometric, spatial, and scientific skills in free play with blocks. They found that when the children engaged in block play activities, spatial, and geometric concepts as well as architectural principles were actualized and that playing with blocks had a positive impact on children's mathematical behavior in general. Through observations of children's free play, Clements (2001) found that children deal with horizontal lines, parallelism, and symmetry while building with blocks. Important conclusions from studies such as these are that

they show the complexity of everyday mathematics where there is an interplay between social interaction and material environment and where interaction with peers drives the children's explorations of geometrical aspects (see also Trawick-Smith et al. 2016).

Studies investigating preschool children's use of gestures and other embodied resources to express geometrical understandings are rare. However, analyzing kindergartners' use of gestures while playing a game in which the children were asked to describe geometrical shapes to their peers, Skoumpourdi (2016) found that the children used gestures independently of talk, producing iconic gestures that mimicked (more or less successfully) the shape that they were asked to describe. Elia, Gagatsis, and van den Heuvel-Panhuizen (2014) studied a five-year-old's learning of spatial and shape concepts in interaction with a teacher in which the child was asked to describe different spatial arrangements of blocks. The results of the study show the role of gestures in using and communicating spatial and shape-related ideas, in particular, deictic and iconic gestures and provide further evidence for the strong interrelations between geometrical thinking and gestures.

Studies of everyday block play activities are still few, and more research is needed (Ness and Farenga 2007). In such a vein, the present study aims to contribute to this emerging field of research with knowledge about how geometrical aspects such as spatiality, shape, and symmetry are actualized in children's verbal and embodied interaction with their peers, pedagogues, and material environment in everyday block play activities.

Mathematizing in interaction

The concept of mathematizing has recently received much attention in mathematics education research (e.g. Reis 2011; Sarama and Clements 2009; Sfard 2008; van Oers 2014). Sfard (2008) defines *mathematizing* as participation in mathematical discourse. Mathematical discourse is a discourse about mathematical objects, where mathematics emerges as a system that 'contains the objects of talk along with the talk itself and grows incessantly "from inside" when new objects are added one after another' (Sfard 2008, 129). Thus, mathematical objects do not pre-exist talk about them but evolve in and through talk. A mathematical discourse involves word use (e.g. words that signify quantities and shapes), visual mediators (visible objects or symbolic artifacts), narratives (e.g. descriptions about relations between objects), and routines (repetitive patterns that are characteristic of a given discourse) (Sfard 2008, 133–134).

We use the notion of mathematization to highlight children's participation in geometrical discourse, emphasizing its collective and colloquial (i.e. everyday or spontaneous) characteristics. Building on an ethnomethodological and multimodal conversation analytic approach (EM/CA) (e.g. Goodwin 2000), we analyze mathematizing as a socially organized process by examining the methods participants use to accomplish social actions in naturally occurring interaction. The concept of *participation* foregrounds the interactive work of both speakers and hearers and provides a framework for exploring 'how multiple parties build action together while both attending to, and helping to construct, relevant action and context' (Goodwin and Goodwin 2004, 240). Participants in social interaction mobilize a set of multimodal resources (talk, embodied action, and material environment) for the locally situated, intersubjective, and methodic organization of interaction. The analyses thus trace how social action gradually evolves; how participants produce intelligible and accountable actions whilst interpreting and acting upon

publicly displayed and mutually available actions. As we analyze children's participation and meaning-making in a block play activity, we explore how young children appropriate a geometric discourse. Children become active participants through their participation in collective activities within cultural settings in which they display their understandings of forms of culturally based knowledge (cf. Aarsand and Melander 2016; Martin and Evalds-son 2012), in our case, understandings of spatiality, shape, and symmetry.

Research method

Video ethnographic fieldwork, empirical setting, and analyzed activity

The analyses are based on video recordings from a seven-month long video ethnographic study documenting mathematical activities in a Swedish preschool (Gejard 2014). The pedagogues actively planned for mathematical explorations as part of everyday life, which was an important reason for conducting fieldwork at this location. The data that will be analyzed here consist of an appr. 22 min. long recording of interaction in the block play area, in which two children, a girl (5.3 years) and a boy (5.2 years), whom we are calling Hanna and Elias, are participating together with one of the pedagogues, Lisa. Hanna and Elias recurrently participated in geometrical activities organized by the pedagogues, such as reading books and talking about geometrical shapes, making shapes from play dough, singing about shapes, etc. thus familiarizing themselves with basic geometric shapes and concepts. The block play area was located in one corner of a large room and it was furnished with a low table with a mirror on top. Along the walls, there were low shelves with building materials that aimed to encourage the children's mathematical explorations. The recorded activity took place before lunch, during free play, when the children were playing with a magnetic construction toy called Geomag. The toy consists of magnetic rods and metal spheres that can be attached to each other (Figure 1). There are plastic panels in the shape of squares, pentagons, and triangles that can be inserted into the shapes created by the rods and spheres.

Analytic approach and ethical considerations

With an interest in how participation is organized within the block play activity, and how the participants orient to spatiality, shape, and symmetry, the analysis follows the unfolding organization of one activity. Detailed attention is paid to how geometry is made relevant in children's interaction with their peers, pedagogues, and the material environment by analyzing the verbal and embodied resources (including talk, gestures, gaze, body positioning, body movements, and object manipulation) that participants draw upon to construct social action (e.g. Goodwin 2000). The children recurrently participated in block building play and the activity chosen for analysis is a typical example of what the children do in the blockplay

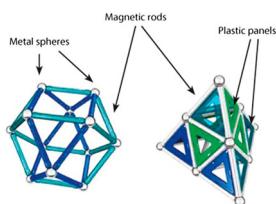


Figure 1. The Geomag magnetic construction toy.

corner and the geometry that is actualized during these activities. The excerpts selected for analysis contain references to lexical items that indicate spatial categories: spatial location (e.g. up, down etc.), spatial dimension (e.g. long, high etc.), spatial features or properties (e.g. curvy, straight etc.), shape (e.g. rectangle, square etc.), spatial orientation or transformation (e.g. turn it around etc.), and deictic terms (e.g. here, there etc.) (cf. Ferrara et al. 2011). The excerpts have been transcribed using conversation analytic conventions (see Appendix). In order to highlight embodied actions and the participants' orientations to the material environment, drawings based on frame grabs from the videos are included in the excerpts.

Written consent has been secured from the participating pedagogues as well as the children's guardians. The children were informed about the study and their right to choose whether they wanted to participate in the recordings or not during fieldwork. All participants have been given pseudonyms in order to protect their identities.

Mathematizing in the block play area

The analysis traces the evolving organization of a block play activity and we will show how the children make relevant a geometrical discourse while building. The first part of the analysis (Excerpt 1) demonstrates how the children orient to a number of spatial categories as they work with their constructions. In the second part of the analysis (Excerpt 2), one of the children asks the pedagogue a question that initiates a sequence in which they collaboratively explore geometrical shapes and spatial properties. Then follows a section in which spatial orientation and transformation are actualized as the children have decided to join their two constructions into one (Excerpt 3). Finally, the last part of the analysis (Excerpt 4) shows how symmetry plays a significant role as the children negotiate the design of the joint construction. Throughout the activity, Elias is sitting on the table and Hanna is on her knees on the floor opposite Elias. The pedagogue watches over the children, sometimes commenting on the constructions or responding to the children's questions.

Making relevant different spatial categories

We will begin by showing how the children make relevant spatial relationships. The excerpt is from the beginning of the activity, and the children are working on two different constructions. However, they actively engage in each other's projects by commenting upon them. In the first part of the excerpt, the children show each other their constructions, highlighting something 'worth seeing', whereas in lines 12–16, the two constructions are compared to each other.

In line 1, Elias calls for Hanna's attention with an instruction to look into his construction as he points at it, thus establishing a joint focus of attention. Hanna bends down, looks from the side, and responds by producing a response cry *wɔ:w* (Goffman 1978) followed by a sound object *eeh*, thereby showing appreciation of his structure (fig. 1.1). Elias elaborates on the feature that Hanna should observe: *it looks like a- (it's a) hole* (line 5). Rather than responding to the description of the construction in terms of a hole, Hanna produces a similar attention-seeking utterance: *look, now it looks like there are three: on mine* as she points at the bars (fig. 1.2). The utterance reuses resources provided by Elias' prior action to highlight an aspect of Hanna's construction, a way of building new action by performing operations on existing actions, something that has been shown to be central to

Excerpt (1): Look into mine
[22-130305; 00.40-02.10]

- 1 Elias Hanna, +kolla i:n i+ mi:n:.
Hanna, look in:to mi:n:e.
+points at his construction+
- 2 *(1.5)*
- 3 hanna *bends down and looks from
the side of the construction*
- 4 Hanna o:j eeh
wo:w eeh
- 5 Elias +de ser ut som ett- (de e ett)++hå:l.
it looks like a- (it's a) ho:le.
+observing his construction from above+
+looking from the side+

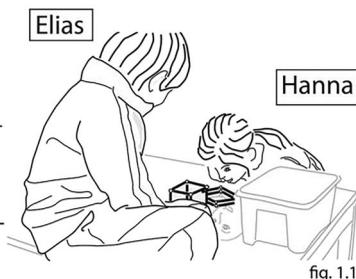


fig. 1.1

- 6 Hanna kolla, nu ser de ut som de e *tre:* på min.
look, now it looks like there are three: on mine.
points
- 7 Elias +nejj (0.8) d- (1.8)+ ko+lla hä:r.+
noj (0.8) i- (1.8) look he:re.
+observing Hannah's construction from different sides+
+points at one of the horizontal bars+



fig. 1.2

- 8 +(4.1)+
- 9 hanna +adds another horizontal bar+
- 10 Elias sätt +såna här.+
put these kinds.
+points at a vertical bar
in his construction+



fig. 1.3

- 11 (1.1)
- 12 Elias ja ska bygga ett sånt högt:
I'll build such a high one:
(60 sec. omitted)
- 13 LISA oj(hh), (.) +kolla vad läckert, det ser ut som
wow(hh), (.) look how cool, it looks like
+points at Elias' construction and on the mirror->+



fig. 1.4

- 14 jätte-+ (.) flera flera våningar (.) fyra våningar
really- (.) several several floors (.) four floors
lisa ->+
- 15 (1.1)
- 16 Hanna men mitt kommer va längre upp.
but mine will be higher up.

Figure 2.

how participants grasp the meaningfulness of the ongoing interaction (Goodwin 2013). Observing the construction from different sides, Elias rejects Hanna's observation: *no ;(0.8) i- (1.8) look he:re* while pointing at one of the horizontal bars of her construction, possibly orienting to the fact that from his perspective the construction has four levels (2 in the construction +2 that are reflected in the mirror). Hanna continues building without attending to Elias. He does not further elaborate but watches her, and then suggests that she put additional bars in her construction by saying *put these kinds*. (line 10), pointing with an open hand to his own construction (fig. 1.3), emphasizing its height by moving his hand along the vertical bar. When no uptake is forthcoming from Hanna, Elias picks up some bars and declares *I'll build such a high one;* as he continues his own project.

After a minute when the children have continued to build (not in the transcript), the pedagogue makes relevant the height of Elias' construction. Pointing at the construction and the mirror, she reorients to what Elias said in line 12 by producing a response cry followed by a positive assessment – *wow, (.) look how cool*. She moves her pointing finger up and down along the side of the construction as she twice repeats 'several' and points down into the mirror, thus emphasizing its height and how it is reflected in the mirror, specifying the height of the building as *four floors*, referring to how the building appears in the mirror (2 + 2) (fig. 1.4). After a brief silence, it is Hanna who responds by declaring that hers will be higher: *but mine will be higher up*. The utterance is responsive to the pedagogue's positive assessment of Elias' work, where Hanna compares her future construction with the one that has just been assessed.

When building with the construction toy, different spatial categories are actualized. When Elias tells Hanna to look 'into' his construction, this indicates direction and is related to spatial locations. By referring to a 'hole' (line 5), the three-dimensional aspect of the construction, space, is highlighted. The children also use words that refer to spatial dimensions, such as when Elias declares that he will build 'such a high one' (line 12; cf. Ferrara et al. 2011). This can be contrasted to Hanna's 'higher up' (line 16) that is a location word; location words describing the position of an object, whereas dimension words describe the size of an object relative another object (Ferrara et al. 2011). The participants use *environmentally coupled gestures* (Goodwin 2007), that is, actions that rely upon talk, embodied action (pointing gestures), and the material environment, thus creating a powerful multimodal package of complementary meaning-making practices. Pointing gestures in combination with deictic terms are for example used by Elias to identify an object to attend to: 'look here' (line 7) and 'put these kinds' (line 10). The powerfulness of these combinations is displayed in how the children with rather limited verbal resources ('put these kinds') produce interactionally meaningful actions.

Exploring geometrical shapes and spatial properties

Between excerpts (1) and (2), the children have rebuilt their constructions. Hanna is now working on a cubic shape, similar to Elias' construction. In the analysis of excerpt (2), we will demonstrate how shapes and spatial properties are made relevant, as Hanna explores her construction by orienting to its straightness. The construction consists of magnetic rods and metallic spheres but no plastic panels, making the construction flexible and slightly unstable. Hanna holds her construction up in the air and asks the pedagogue if it is straight. Her question initiates a sequence in which Lisa and Hanna explore shapes and their properties.

Excerpt (2): Is mine straight?
 [23-130305; 02.03-02.32]

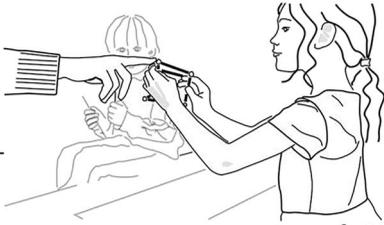
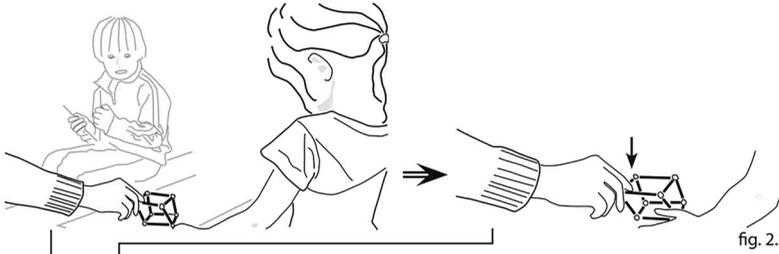
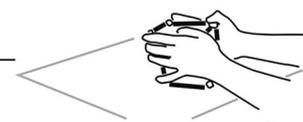
- 1 Hanna e min ra: *+k?
 is mine strai:ght?
 holds her construction in the air, showing Lisa->
- 2 (1.5)
- 
- 3 LISA ja:ɛ d- (1.0) †titta. de e *li:ka långa† sider alla.* fig.2.1
 yeahɛ i- (1.0) look. all the sides are e:qually long .
 †points at one of the sides†
- 4 hanna -> *drops the construction on the mirror
 so that it becomes distorted*
- 
- 5 LISA >†fast nu-†
 but now-
 †presses one of the sides†
- 6 *(2.0)
- 7 hanna *straightens the construction so that it retains its cubic shape->*
- 8 LISA e den inte riktigt ra:kɛ nu blir de som en=
 isn't it really strai:ghtɛ now it'll be like
- 9 LISA =annan [fo:rm.] (.) än en kvadrat- (.) kub,
 another sha:pe. (.) than a square- cube,
- 10 Hanna [mm*]
 ->*
- 
- 11 Hanna jag måste använda *såna [*hå:rɛ]* fig.2.3
 I've got to use some of the:seɛ
 takes a square panel from the box
- 12 Elias [+tre plus tre blir sex.+ (1.0)
 three plus three is six.
 †holds bars in the air, showing Lisa†
- 13 LISA ja: †de blir e.
 yea:h †it is.
- 14 Hanna *de e de bästa du ve:tɛ ((singing))
 it's the best you kno:wɛ
 attaches a panel to the construction->
- 
- 15 Hanna nu kommer den inte att *va sne:.*
 now it won't be twis:ted.
 -> *straightens the shape*

Figure 3.

By asking the pedagogue *is mine straight?* (line 1), Hanna is making relevant spatial properties of her construction. The pedagogue hesitatingly confirms, possibly because of the fact that the construction has become slightly twisted as Hanna is holding it in her hands (fig. 2.1) and initiates a description of the construction *yea:h₂ i- (1.0) look. all the sides are e:qually long.* (line 3) as she points along one of the side bars. The question of straightness is responded to as being about the equally long sides. Hanna drops the construction on the mirror, distorting its shape. The pedagogue uses this as an educational resource, and she points and presses at the construction so that it becomes oblique, acquiring a rhombic shape (fig. 2.2). She comments on the shape of the construction, describing it as not really straight (line 8) and as being of a different shape (line 9). During this utterance, Hanna has straightened the construction (fig. 2.3), and Lisa continues by elaborating on the type of shape *than a square-cube*, (line 9). The pedagogue thus introduces a geometric discourse by first describing the construction as having equally long sides – the defining criteria for the geometric shapes square and cube. The notions are introduced as she denominates the object as having a different shape than a square, which is repaired by replacing *a square* with *a cube*. The former is not incorrect as a cube consists of six identical squares, but by using the term cube she makes relevant the three-dimensional shape of the construction. Hanna, who is still oriented to the spatial properties of the object (straightness), picks up a square panel, attaching it to the construction so that it acquires a straight shape: *now it won't be twisted* (line 15, fig. 2.4).

In excerpt (2), the participants use the flexibility of the magnetic construction toy to explore geometrical aspects. Hanna has been demonstrated to mainly orient to spatial properties of the object under construction, whereas the pedagogue oriented to the geometrical shapes (square, cube, equally long sides) that emerge as the construction is manipulated and transformed (cf. Ferrara et al. 2011).

Explaining spatial transformation and orientation

We will now show how geometrical aspects connected to spatial transformation and orientation are made relevant as the children decide to join their two constructions into one. The constructions are identical and in the shape of two cubic houses with a roof and a door. In similarity to how the pedagogue in excerpt (1) talked about Elias' construction in terms of having several floors (line 14), the children now talk about their constructions as representations.

Excerpt (3): You can turn it like this
 [23-130305; 08.27-09.01]

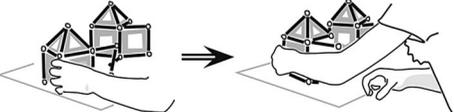
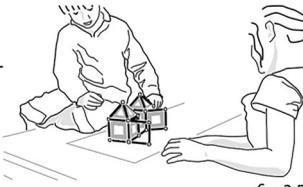
- 1 Hanna *i de här genomskinliga ↑hu:set. (.) skulle ↑du vilja bo* här?=
 in this transparent ↑hou:se. (.) would ↑you like to live here?=
 adding a panel to the roof of the construction
- 2 (1.5)
- 3 Hanna =*då måste ja ta bort min* dörr.
 then I have to remove my door.
 turning the construction
- 4 Elias >varför?
 >why?
- 5 *(1.0)*
- 6 hanna *removes the panel from her door*
- 7 Hanna för att-
 because-
- 8 *(1.0)
- 9 hanna *leans back, left hand to the chin with a panel in the right-->*
- 
- fig. 3.1
- 10 Elias (de går å röra den-) +du kan vända den så+ här
 (you can move it-) you can turn it like this
 +pointing at Hanna's door+
- 11 (.) som jag har,
 (.) like I have,
- 12 *(8.0)*
- 13 hanna *reattaches panel on the door, removes it
 and holds left hand on the roof of the construction*
- 14 Hanna >hur menar du?<
 >how do you mean?<
- 
- fig. 3.2
- 15 Elias +ja stäng- ja ha inte på den sidan. ja gör så här?+
 I close- I don't have on that side. I do like this?
 +wiggling the door back and forth+
- 16 Hanna °okej?°
 °okay?°
- 17 *(2.0)*
- 18 hanna *turns her construction*
- 19 Hanna ↑så:,
 ↑like tha:t,
- 20 (2.0)
- 
- fig. 3.3
- 
- fig. 3.4
- 21 Elias sen *ska vi sätta ihop dom så?<*
 then we put them together like that?<
- 22 hanna *joins the two constructions*
- 
- fig. 3.5

Figure 4.

Hanna frames the activity as a playful event when she asks Elias *in this transparent ↑how: se (.) would ↑you like to live here;* (line 1). After a short silence during which Hanna and Elias both gaze at Hanna's construction, Hanna says that she needs to remove her door (line 3), thus identifying the door as an obstacle to the joining of the two constructions. Elias immediately asks Hanna why. Hanna removes the plastic panel from the door and then initiates an answer (*because-*) that is abandoned, thus displaying her difficulty in providing an account for why the door should be removed. Hanna's construction is placed on the mirror with the door directed toward Elias' construction, whereas Elias' construction is positioned with the door facing Hanna (fig. 3.1). Hanna thus seems to be oriented toward joining the constructions on her door side but displays uncertainty by leaning back and moving her hand to the chin, observing the constructions from some distance.

Elias produces an instruction (*you can move it-*) *you can turn it like this (.) like I have* (lines 10–11), touching the door on Hanna's construction as the first part of the utterance is produced, then briefly pointing at his construction, tracing the direction of the door (fig. 3.2). He thus suggests that Hanna turn her construction in the same direction as his. An 8 sec. silence follows, during which Hanna first reattaches and then removes the plastic panel on the door to then hold the construction with her hand on the roof, in all displaying that she is uncertain about what to do. A request for an explanation follows as Hanna asks *> how do you mean;<* (line 14). Elias answers *I close- I don't have on that side. I do like this;* as he wiggles the door, back and forth. The utterance is produced with several reformulations, displaying his difficulty to find words to explain what he means. He makes relevant direction ('that side') and describes a movement ('I do like this'). Hanna silently receipts Elias' explanations and then turns her construction, placing it in the same direction and with the same orientation as Elias' construction (fig. 3.4). The constructions are aligned and as Elias says *then we put them together like that;* Hanna joins the two constructions (fig. 3.5).

The fact that the constructions are identical but placed in different directions poses problems to the children when joining the two constructions. It is a challenging task, but the children display a high level of engagement in the activity and a resolution to solve the problem, something that is visible in the way that they make suggestions, ask questions, and attempt to explain to each other what to do and why. The complexity of the task is shown by the children's difficulties in providing verbal explanations and where they instead rely upon pointing gestures, deictics, and embodied demonstrations ('you can turn it like this', 'I do like this') to indicate what they are referring to (e.g. lines 10, 15) (cf. Elia, Gagatsis, and van den Heuvel-Panhuizen 2014). The problem that they are facing has to do with direction, spatial orientation, and transformation (mental rotation, Casey et al. 2008). The way Elias' talk is produced with restarts and reformulations (lines 10–11, 15) demonstrates the complexity of describing an orientation or an act of moving objects in space. In addition, Hanna displays difficulties in finding out in what direction to turn her construction, but once she finds out what to do she rather quickly rotates it so that it ends up in the same direction as Elias', an action that can be understood as a precursor to mental rotation.

Negotiating symmetries

In this last section, we will highlight how the children make relevant symmetries as they negotiate the design of their construction. Between excerpts (3) and (4), the children

have been working on their joint construction. The positions of the doors are the same, but they have joined the two doors with vertical bars (fig. 4.1). Hanna, who focused on the position of her door in excerpt (3), now argues that they have to change the position of Elias' door.

Excerpt (4): You've got to have your door there
[23-130305; 10.13-10.48]

- 1 Hanna ↑men (.) din dörr* måste ju sitta ↑dä:r,*
↑but (.) your door has to PRT sit ↑the:re,
points
- 2 Elias °mm,°
- 3 (3.0)
- 4 Elias +då behöver +vi ta bort (.) en sån+ här.
then we have to remove (.) one of these.
+points at a rod +
- 5 Hanna °ja:°
yes
- 6 *(1.0)
- 7 hanna *removes rod->*
- 8 Elias för då blir båda raka.
because then both become straight.
(2.0)
- 9 Hanna så:*?
like tha:t?
->*
- 11 Elias +så sätter vi ihop dom+ så. (.)
then we put them together like this. (.)
+joining the two rods that are left+
- 12 de +måste ju+ också va en här nere?
there has to [PRT] be one down here too?
+adjusting the only bottom rod+
- 13 Hanna du +måste ha din dörr där+
you've got to have your door there
+points at one of the bars beside Elias door+
- 14 (1.0)
- 15 Hanna uhu uhu ((coughs))
- 16 Elias °mm°
- 17 (2.0)
- 18 Elias +då måste vi+ ha f- +>en till.<+ då mås-
then we've got to have f- >one more.< then we've go-
+gaze at Hanna+ +touches bar of door but does not remove it+
- 19 nej de behöver vi inte.
no we don't need to.

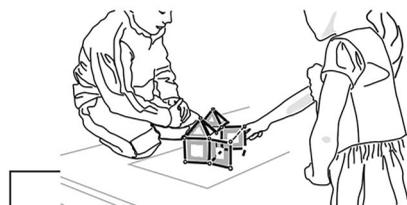


fig. 4.1

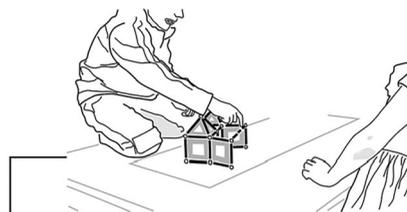


fig. 4.2



fig. 4.3

Figure 5.

Hanna orients to the problem that she perceives with Elias' door, which is that his door should be positioned further out on the construction. She points at the lower right end, indicating the correct position of the door (fig. 4.1) and saying ↑*but* (.) your door has to [PRT] *sit* ↑*there* (line 1). Elias minimally acknowledges, but rather than immediately responding to the position of the door, suggests that they remove a rod as he points at one of the bars between the two doors (fig. 4.2). Hanna, answers *yes* in a quiet voice, and then begins to remove one rod. Although the action is already on its way, Elias produces an account at this time, explaining why it was necessary to remove the rod: *because then both become straight*. (line 8), an utterance that refers to the two doors that will be straight in relation to each other. That Elias orients to straightness is reinforced as he helps Hanna adjust the rods and comments on the collaborative construction: *then we put them together like this*. (.) *there has* [PRT] *to be one down here too?* (lines 11–12). Adding a bar at the bottom of the construction increases its stability. The Swedish epistemic adverb 'ju' appeals to shared knowledge, meaning that the claim that there has to be a bar at the bottom is produced as something that both Elias and Hanna (should) know (Heinemann, Lindström, and Steensig 2011). However, before either child has added a bar, Hanna, who has actively engaged in Elias' project of straightening the construction, returns to the question of the position of the door, *you've got to have your door there* as she points at the far right side of the construction (line 13, fig. 4.3). She emphasizes 'your', 'door' and 'there', in all underlining crucial parts of the directive. After a silence and a minimal acknowledgment Elias aligns with Hanna's directive and moves his hand to the door, trying to detach the door from the construction (line 18). However, he quickly abandons the attempt and instead declares *no we don't need to*. This is accounted for by Elias (not in the transcript) by suggesting that the far end of the construction is an entrance, something that Hanna agrees with and the discussion about the door position comes to a close.

While building, the children make relevant spatial categories such as spatial properties ('straight'), spatial location ('there'), and spatial position ('down here'). Deictics are frequent and combined with pointings they highlight relevant aspects of the construction. The use of deictics presupposes that the addressee is attending to a specific place on the construction (see Goodwin 2007). The way in which the children work to secure each other's attention, attempting to establish a shared understanding of the activity at hand, is crucial for how they manage to collaboratively build a complex construction.

As the children negotiate the design of their construction, they create and combine different shapes and as the construction gets more complex they have to figure out how to coordinate the parts into a connected whole (cf. Casey et al. 2008, 272). In this process, they make relevant symmetry. On the one hand, changing the door position the way Hanna wishes would create a symmetrical mirrored construction, where what Hanna is orienting to is plane symmetry (Ness and Farenga 2007). On the other, Elias orients to symmetry when he suggests that they remove a rod (line 4) so that the doors 'become straight' (line 8), or in other words that the rods become parallel to each other, thus reinforcing the straightness of the shape. This is an example of line symmetry, where an object is placed equidistant from the sides of a larger structure, creating a symmetric appearance (Ness and Farenga 2007).

Concluding discussion

Children's participation in incipient geometrical discourse

In this paper, we have explored mathematizing in a naturally occurring, everyday block building activity, with an interest in children's displayed understandings of geometry. Through the detailed analyses of the unfolding organization of the activity, grounding the analyses in the participants' orientations rather than in predefined categories, we have shown how the children orient to and actualize different geometrical aspects as they work on their constructions: spatial locations, properties, dimensions, orientations, transformations, and geometrical shapes. The results of the study show the richness of children's spontaneous mathematical interactions and the number of geometric aspects that arise in their interaction as they proceed to collaboratively solve the problems that they encounter (cf. Clements 2001; Ness and Farenga 2007).

Describing the characteristics of a mathematical discourse, Sfard (2008, 133) highlights the importance of the words that participants use, as they are responsible for 'what the user is able to say about (and thus to see in) the world'. When the children in our data interact in the block play activity, they use different linguistic resources where some directly refer to geometrical concepts, for example, 'is mine straight'. More importantly, however, the children rely on unspecified notions and deictics such as 'look into mine', 'I've got to use some of these', 'put these kinds'. Elia, Gagatsis, and van den Heuvel-Panhuizen (2014) demonstrate how a child spontaneously used iconic and deictic gestures throughout a construction activity in order to describe different geometric shapes and relationships. In a similar vein, Skoumpourdi (2016) shows how children use different communicative modes to describe shapes and how gestures were found to function independently of oral language. In contrast, the results of our study show the symbiotic relationship between talk, gesture, and material environment, where talk and gesture mutually elaborate upon each other as part of collaborative meaning-making practices (cf. Goodwin 2000, 2007; Sfard 2009). Together with pointings and gestures, that in a simultaneous and coordinated way are used to indicate specific objects, directions, or places, the children produce meaningful and mutually intelligible actions that contribute to and are indeed a condition for how the activity and the construction develops over time, from a number of metallic spheres and rods that are combined into two cubic shapes that are later joined and transformed into a complex building. The physical manipulation of the objects are here part and parcel of the children's geometrical discourse (cf. Sfard 2008, 148), and the material environment, that is, the Geomag construction toy, the mirror as well as how the children are positioned around the table, all contribute to the exploration of spatial phenomena such as height or straightness. In other words, the results of our study demonstrate the intertwinedness of talk, embodied actions, and the material environment in children's mathematizing, aspects of children's displays of mathematical understandings that only to a very limited extent have been investigated in previous research on preschool mathematics and geometry.

The children in our data are clearly newcomers to mathematical discourse, but through their active participation in everyday block play activities such as the one analyzed here, we argue that they appropriate an incipient geometrical discourse as it emerges in the unfolding flow of interaction. However, the research reported here calls for more studies on children's development of understandings of geometry as they are actualized in everyday,

naturally occurring interactions – both in spontaneous play activities and in instructional activities organized by pedagogues. Our study represents a very first step in this direction and more research is needed in order to fully grasp the relation between talk, embodied actions, and other semiotic resources and its relevance for young children’s development of geometrical thinking.

The findings reported in this study can inform pedagogues about ways of thinking of geometrical discourse as embodied, situated, and in dialogue with a material environment (cf. Elia, Gagatsis, and van den Heuvel-Panhuizen 2014). Our findings underline the importance of striking a balance between, on the one hand, controlling the children’s activities, providing them with correct concepts and explanations and, on the other hand, letting their actions drive the activity forward, allowing them to explore geometrical shapes and relations in unpredictable ways. The detailed analyses of multimodal interaction in everyday activities may help pedagogues become aware of children’s geometrical knowledge that goes beyond verbal articulations of geometric concepts, in order to identify learning needs and to design pedagogical challenges.

Note

1. We use the word ‘pedagogue’ to denominate staff working at the preschool, as this was the way the participants in the study referred to themselves.

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No potential conflict of interest was reported by the authors.

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Appendix

Transcription conventions

(Jefferson, 2004, for embodied actions Mondada, 2009)

[]	Overlapping talk
=	Equal signs indicate no break or gap between the lines.
(0.8) (.)	Numbers in parentheses indicate silence. A dot in parentheses indicates a micropause.
. , ¿ ?	The punctuation marks indicate intonation. The period indicates falling intonation, the comma continuing intonation, the inverted question mark slightly raising intonation, and the question mark indicates rising intonation.
::	Colons are used to indicate prolongation or stretching of the immediately prior sound.
-	A hyphen after a word indicates a cut-off or self-interruption.
<u>word</u>	Underlining indicates some form of stress or emphasis. The more the underlining the greater the emphasis.
WOrd	Especially loud talk is indicated by upper case.
° °	The degree signs indicate that the talk between them was quieter than its surrounding talk.
↑	The up arrow marks a sharp rise in pitch.
< >	Left/right carats indicate that the talk between them is slowed down.
.h .hh	Hearable inbreaths are shown with a ".h" – the more h's the more inbreath.
()	Empty parentheses indicate that something is being said but no hearing can be achieved.
**	Gestures and actions descriptions are delimited between two identical symbols (one symbol per participant) and are synchronized with corresponding stretches of talk.
->	Gesture or action described continues after excerpt's end.
*->	Gesture or action described continues across subsequent lines until the same symbol is reached.
->*	
LISA	Name in upper-case indicates pedagogue
Hanna	Name in lower-case indicates child
hanna	Participant doing the gesture is identified when s/he is not the speaker.