

YOUNG CHILDREN'S USE OF MEASUREMENT CONCEPTS

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This paper describes preschool children's measurement representations as they engaged in drawing a map. The use of small cars, boats, trains and aeroplanes helped the children to make the connections between two and three dimensional space. They also made connections to their understandings of length. The children's own experiences provided the motivation and stimulus to provoke their mathematical thinking about quantifying different attributes of objects.

Keywords: preschool children, outside preschool experiences, measurement, attribute, unit,

INTRODUCTION

In this paper, I focus on children's experiences of area and different forms of length, such as breadth and height, by analysing the children's descriptions as they drew a map. The children's own thoughts were used as a starting point to discuss the mathematics by myself, as the teacher. This case study is a part of a larger study which arose from a desire to understand how children's outside experiences can promote mathematical learning.

Doverborg and Samuelsson (2011) highlighted the need for children to learn from their own experiences in a way that made sense to them. Their research indicated how children perceived mathematics to be useful both at the current time and in the future. However, Uttal (2000) found that children's developing conceptions of maps were affected by their understanding of the surrounding world. Uttal suggested that younger children perhaps have not yet developed the ability to understand and connect their outside experiences to activities inside preschool. Uttal's study showed children's difficulties in encoding, remembering or understanding information. He suggested that to capture and comprehend all aspects of a three dimensional world on to a two dimensional sheet of paper is impossible for young children.

According to the Swedish preschool curriculum, early childhood settings should facilitate mathematical learning through play (Skolverket, 2011). Play has a leading role in developing children's knowledge from an early age (Vygotsky, 1933/1966). Activities can be based on a creative form of play, with opportunity for a variety of expressions. Children's everyday experiences can be represented in their visual creativity and provide opportunities for conversations. Nevertheless, it can be difficult to see children's illustrations with anything other than the adult eyes, but when we listen to children, as they draw, we can understand their thoughts, thus providing insights into their interests and background (Coates & Coates, 2006).

Social interaction in play can promote the construction of mathematical knowledge. Edo, Planas and Badillo (2009) stressed that teachers and children interactively construct shared meanings when engaged in activities, such as play. Consequently, the preschool teacher has to find meaningful situations and ways to communicate that challenge the children to ask questions, reflect and discuss the situation (Clarke, Clarke, & Cheeseman, 2006). The conversation between adults and children can be a part of the learning process in mathematics, where the teacher has a supporting role to help the children build an understanding of measurement.

When children attend preschool they bring with them experiences from outside preschool which can be the basis for developing children's mathematical thinking (Clarke & Robbins, 2004). However, teachers' perception that they must follow the curriculum can result in them providing activities suggested by the curriculum but which do not build on children's own understandings (Doverborg & Pramling Samuelsson, 2011).

MEASURING CONCEPTS USING CHILDREN'S OUTSIDE PRESCHOOL EXPERIENCES

Concepts of measurement are described in relationship to the concepts of attribute, unit and scale (New Zealand, Ministry of Education, 2007). The attribute that is compared can be area, length, volume and time, etcetera. Unit and scale measurement concepts can be applied to most attributes but initially it is very important for children to be able to identify what attribute is to be measured (New Zealand, Ministry of Education, 2007). Once the attribute is identified, children are then able to do direct comparisons by placing two objects next to each other. They also develop an understanding of transitivity, in which a third object is used to compare two other objects. If the first object is smaller than the third object but bigger than the second object, it is possible to say that the first object is smaller than the third object.

In measurement, units are used to measure an attribute and to quantify the amount of an object. Bush (2009) described children's understanding of measurement, with focus on usage of identical units and iteration. For an accurate measure, the units must be identical. Iteration is the repetition of a unit to measure and is one of the underlying concepts connected to unit. For children to have an understanding of tiling, they need to understand that units are placed repeatedly, with no spaces between, in order to measure the amount of an attribute. These are counted in order to find the measurement amount (Bush, 2009). Relativity involves understanding how units compare in size to other known objects (New Zealand, Ministry of Education, 2007). McDonough and Sullivan's (2011) research suggested that children also need to understand that a larger unit can be subdivided into repeated parts which can be counted, to produce a measurement of the object. This concept leads to the use of standard units.

When using a scale to measure, any point can act as the start or end point. However, without an awareness of the concept of unit, incorrect measuring can occur (McDonough & Sullivan, 2011). The concept of scale also includes an understanding that marks on a scale represent the end point of each of the units. Therefore, the end point when something is placed on a scale, indicates the amount in the same way that counting individual units does (New Zealand, Ministry of Education, 2007).

The Swedish preschool curriculum suggests that the preschool should engage children in activities that develop their ideas about measurement and space, as well as other mathematical concepts (Skolverket, 2011, p. 10). This means that teachers are responsible for building on children's understandings of attribute, unit and scale as they engage in an activity.

Children's everyday experiences outside preschool can be a starting point for building measurement strategies in preschools (Castle & Needham, 2007). Clarke and Robbins (2004) collected data, that showed children's experiences at home and in their neighbourhood and captured a variety of mathematical contexts. There were sequences of children measuring ingredients and cooking at home. These provided evidence of mathematics in everyday experiences, although they were not recognized by parents or teachers. Meaney (2011) also found that a six-year old girl engaged in a number of measurement activities at home, often associated with the child's physical engagement in a task. In particular, she suggested that measurement of time, often considered hard because of its abstract nature, was focus of many discussions between the child and her mother. This contradicts suggestions that length is the easiest attribute to measure.

Fleer (2010) suggested that younger children in preschool probably are unaware of the value of their own experiences and the teacher has to encourage this awareness. Within preschools, there are possibilities for knowledge creation, nevertheless children should have the opportunity to form their own experiences and make choices in the light of these.

There appears to be little research which shows how children's share their previous measurement experiences and then teachers make use of them to develop their understandings. For example, Castle and Needham (2007) investigated younger children's understanding of measurement concepts, but not their thoughts about them. In McDonough and Sullivan's (2011) research, children were assessed preconceived understandings about how children learn length measurements.

The aim of my research is to understand how children's outside experiences can promote mathematical learning. Teachers' ability to recognize and work with children's outside preschool experiences can affect the mathematical activities that they offer to children. The research question is:

How do children use measurement concepts in an interaction that draws on their outside preschool experiences?

METHODOLOGY

This paper presents a case study (Bryman, 2012), from a larger study. Over recent years, researching early childhood education by listening to and observing children has become common (Dockett, Einarsdottir, & Perry, 2009). A case study approach recognises that within social and cultural settings, children as competent participants have a right to have their voices heard and to be taken seriously. The larger project investigates the relationship between children's outside preschool experiences mathematical learning in the preschool. In this paper, I present one episode in which I was involved as the teacher when children made connections to their outside preschool experiences whilst drawing a map. Their involvement showed use of many of the measurement concepts described earlier.

In order not to lose the spontaneous aspect of the play, field notes, first by myself, but later, after the children invited me into the play, by a colleague were made instead of, for example, video recordings. The latter would have provided the possibility to analysis the data several times. However, given that the wider project was about documenting naturally occurring incidences in a preschool setting, it had been decided to use field notes rather than having a video camera running continuously.

Therefore, I did not set the activity, rather it began as a play session with a group of five children aged between two and six years before breakfast. It was the children, one boy in particular, who suggested drawing a map, which became the focus. From being an observer I became an active participant in the activity, I am aware of that several of the questions that I asked had impact on the dialogue sequences during the activity (Hasselgren & Beach, 1997). However, I was one of these children's preschool teachers and we interacted in ways that appeared typical of our normal forms of interaction.

Analysis of the interactions was done by looking for examples of the measurement concepts of attribute, unit and scale. Examples of the children's use of these concepts are provided in the next section. The exchanges were originally in Swedish but are provided in English. It is not always easy to translate young children's Swedish as their language is developing, so it has been tidied up in places to make it more understandable. This has changed the form and not the content.

CHILDREN'S STRATEGIES IN MEASURING WHILE DRAWING A MAP

The group of five children consisted of three boys and two girls. Child 1 is six years old, child 2 is two, child 3 and child 4 are both five years old and child 5 is four.

Child 1 handed out toy vehicles to the other children, at the beginning of this activity. During the activity, the children shared and swapped toy vehicles between themselves. They all had experiences about travelling and used their knowledge to draw the map. The dialogues show how the children used the toy vehicles with the measurement concepts of attribute, unit and scale.

The activity began with a boy picking up paper and pens. The following exchange then transpired.

Dorota: Why did you take out the paper?

Child 1: We must make space

Dorota: Make space? What do you mean?

Child 1: Space for boats, trains, cars, airport, roads, you can take busses.

Dorota: Are you thinking about a map?

Child 1: We will have roads, airport, harbour, train station. We will find it, we will draw on the paper.

By saying “we must make space”, Child 1 appeared unclear about which attribute he was talking about. However, he clarified this by saying that space was needed for the toy vehicles, suggesting that it was area. After that he said “we will find it”, which was followed by looking at the toy vehicles and the sheet of paper. This suggests that the child was making an estimation to compare different amounts of area that would be needed for roads, airport, harbour, etcetera. However, there is no explicit comparison mentioned either between the different vehicles or between the vehicles and the space on the paper. If there is a comparison, it is implicit. This is similar to what Meaney (2011) found in her study of a six-year old child’s use of measurement concepts. In this study, many of the comparisons were to an unidentified other, making them also implicit.

Later Child 4 helped a younger boy, Child 2, to count busses and draw train stations. Then Child 4 had an idea about drawing a railway and two train stations. She described this to Child 2. Child 4 had experiences of travelling by train and, therefore, may have known that trains travelled from one station to another, although she did not explain why she needed to have two train stations.

Child 4: We are drawing roads and two stations.

Dorota: Why two stations?

Child 4: I do not know, but the train has to go somewhere (Looks at child 2. He had trains, which he gave to her)

The child used physical objects to visualise her thoughts. By saying that the train has to go somewhere, Child 4 implies a comparison between the area taken up by a train, and more implicitly its journeys, and the area on the piece of paper. The presumption seemed to be that the paper had a large enough area to cater for the railway line so the train could “go somewhere”. Child 4 placed the two trains side by side and used them to draw lines on either side of this pair. Then, she moved the trains forward and drew new lines, again either side of the pair of trains and repeated this three times. After that she drew the rest of the railway without using the two trains. She designed a railway across the paper. Each train had the role of an identical unit, as each train was

the same width. In placing the trains side by side, there was no gap between them, suggesting that this child had understood the unit concept of tiling. In this way, Child 4 determined the width of the railway from using the toy trains. After that, she drew a station at each end. This may indicate that she was using them as end points for the length of the railway line, which is related to concept of scale.

The next example shows Child 5's explorations about width, from putting two vehicles side by side and using his experiences and knowledge about traffic and directions. Child 5 started by drawing a road, which he linked to the train station.

Child 5: How much space do I need? I want to have a two-lane street, so my car can drive in both directions.

Dorota: What do you think? How much space does your car need, how wide is the car?

He looked at the car and drew a straight line beside it. He moved the car sideways, and drew another line. The street was compared to how wide the car was. Child 5 used two identical units, the cars, and put them side by side on the road, to see if they fitted into the space. By doing so, he subdivided the width of the road in order that the cars could drive in both directions. The cars were placed side by side with no gaps between, again indicating tiling. He saw the width of the road by placing these cars together in a similar manner to what Child 4 had done with the trains.

The next exchange shows again the importance of the toy vehicles in supporting the children's measurement representation so that they could draw the map as they wanted it to look. The toy cars were not only used to draw roads of an appropriate width, by Child 5, but also to draw a line in the middle of the road.

Dorota: What are you doing?

Child 5: Dividing the road so the cars know on which side of the road they should drive. You know when you drive you should have this line there (pointing at the line, he drew in the middle of the road)

Dorota: Here! On the left side of the car (pointing on the line in the middle)

Child 5's experiences outside of the preschool made him aware the road should be designed so the cars knew on which side of the road they should drive. He placed two cars side by side. Then he took away one and drew a line. These two cars represented the width of the road, which can be considered as a single unit in its own right. In this case, the cars supported the partitioning of this large unit of a road into smaller units, the width of one car. Being able to move backwards and forwards between seeing the car or the road as the unit shows an understanding of the complex relationship between them.

The follow exchange illustrates how child 4, the girl who drew the railway, began to draw a harbour. The harbour was needed because, as the children discussed, it was possible to travel by boat. Child 4 took a pen and drew a line in front of a boat, then

she put another boat behind the first and repeated this until she has five boats, lined up one behind the other, like cars parking in a street, and drew two lines. She said:

Child 4: I'm drawing a harbour, I place my boats behind each other and I have five boats. I have to draw all five to get space

Dorota: Do you make space for your boats?

Child 4: Yes, I know how large a harbour should be now

Dorota: How do you know?

Child 4: My first boat is behind this line (she points) I have drawn two lines now, you see (she takes away the boats and points on two lines)

Dorota: Okay, a line in front of the first boat, and a line behind the fifth boat

Child 4 uses the boats, as physical objects, to find out and measure the area needed for the harbour. To do this, she builds on the attribute idea of comparison, by using length as a default for area measurement. The iteration is of five boat lengths, which forms the area of the harbour, when boats are placed one after the other. Similar to when she was drawing the railway line, child 4 used five identical units and filled a space without gaps, suggesting that she had the unit concept of tiling. By drawing a line at the end of the last unit, she identified the end point for her measurement, which is one of the understandings for the concept of scale. As the teacher, I took the opportunity to use ordinal terms, "a line in front of the first boat, and a line behind the fifth boat" to highlight these endpoints.

A discussion with children in relation to measurement occurred again when the children tried to draw streets and a runway for an aeroplane. The children used each other's ideas to work out how they could make enough space on the paper for vehicles. Child 1 and Child 3 noticed what Child 5 did when he drew roads and did the same with the runway for aeroplanes.

Dorota: How is it going? Do you have space for all the planes?

Child 1: We have five aeroplanes and only two can be in air.

Dorota: Be in the air?

Child 1: One lands, and one lifts off (he points to the map), you see, we have drawn a take-off and landing runway. Other planes are here.

Dorota: Okay, what were you thinking when you drew the runway?

Child 1: The aeroplane takes a lot of space, we have tried.

The children needed the support of physical objects when, for example, they discussed the width of a runway to make sure it would be possible to fit an airport on the map. Child 1 took two aeroplanes and placed them on the runway, side by side. In this way, he compared the width of an aeroplane to the width of the runway. By placing two aeroplanes on the runway side by side, Child 1 and Child 3 used the

concept of iteration, to measure the width of the runway—it was two aeroplanes wide. They used aeroplanes to determine the size of the area that they had to draw, by lifting one aeroplane and landing the other.

Sometimes physical objects were not sufficient for developing some ideas and it was myself, as the teacher, who provided the stimulus. When it was time to draw a bridge, I challenged them to think more about height and width. To begin with, I took a piece of paper and said “how long should the bridge be?” A girl replied, “as long as a car”. Then I cut a piece of paper, so that it was as long as the car the girl gave to me.

Dorota: Is it a bridge? (I looked at Child 4. who put the piece of paper on the map), is it a bridge?

Child 4: No, how should we make one? What should we do?

Dorota: (took a larger piece of paper, gave it to child 5) Can you cut out a strip, which has the same width as this piece (the piece child 4 cut, which was too short). It is as wide as two cars. This has sufficient width to be a road in two directions.

Child 4: We take two cars, put them on the piece of paper, one after the other. Is it enough?

Dorota: How do we know that the bridge has enough width and height to allow a train to drive under?

Child 5: A train must be able to drive under the bridge, we try (teacher takes a train, holds up the piece of paper and pushes it upwards until there is space enough to drive the train under it.)

Child 4 together with child 5 wanted to build a bridge for cars to drive over and trains to go under. The width of the paper was compared to the width of two cars. Child 4 said “we take two cars, put them on the piece of paper, side by side and cut”. In placing two cars side by side, they showed a concept of iteration. The cars were identical units and these units filled the space without gaps, thus tiling was used. Relativity in measurement takes place, when they needed to cut a piece to fit two kinds of units, cars and trains. The piece of paper, the cars and trains, are compared directly.

DISCUSSION AND CONCLUSION

This activity was initialized by the children and the map was a product of their engagement. To produce the map, the children used several measurement concepts to solve problems. I consider the children’s creativeness, in map making, to be the key for making connections between their ideas about how to measure and the mathematical phases in measurement described in the literature (Bush, 2009; New Zealand Ministry of Education, 2007; McDonough & Sullivan, 2011). The children used informal units, such as the toy cars, boats and places, to measure attributes of

objects, such as the area for a harbor, the width of a road, height of a bridge and length of the airport runway.

The results of this study indicate that children's own experiences were the background for the activity and could be drawn upon whilst they were playing. Using their own experiences allowed them to link the knowledge they possessed with knowledge about measurement concepts. The activity allowed them to be creative. At times, they were not able to express their thoughts verbally but did so through gestures, when they were using the physical objects.

As a teacher I could recognise the mathematics in children's actions and drew their attention to concepts of measurement, especially in the bridge episode. I could help children to address challenges they had when building the bridge. The knowledge that the children had about the need for the bridge to be tall enough for a train to go over it and wide enough for two cars to travel over it provided them with background to what the problem was that they had to work on. Their understanding of what the problem was meant that my questions prompted them to think again about how long the paper for the bridge needed to be.

As Doverborg and Pramling Samuelsson (2011) stressed there is a need to use children's own experiences as a basis for their mathematical activity. In this case study, children's outside preschool knowledge about travelling and their experiences with cars, trains, planes and boats allowed them to use and develop their understandings about measurement concepts. This illustrated how Doverborg and Pramling's ideas could become a reality when children are supported to discuss their ideas. As the teacher, by engaging in their play, I conformed the value in these experiences through the social interaction and promoted the construction of mathematical knowledge. In many ways this was similar to what was documented in Edo, Planas and Badillo's (2009) research. Listening to what the children had to say contributed to finding a meaningful situation, in which it was possible to challenge the children to ask questions, reflect and discuss (Clarke, Clarke, & Cheeseman, 2006).

Further research is needed to understand how children's background knowledge can be used by preschool teachers in activities and discussions. The research described in this paper has shown how concepts of measurement can be used but further research is needed about how other mathematical concepts can be developed by preschool teachers drawing on children's outside preschool experiences.

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