

Chapter 6

Inscriptional Capacities and Representations of Young Children Engaged in Data Collection During a Statistical Investigation



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Abstract Recent research has provided important insights into young children's statistical reasoning when engaged in core components of data modelling, namely attribute selection, data representation and metarepresentational competence. The research described in this chapter, however, explores the stage prior to attribute selection—the collection of data. We describe young children's inscriptions when collecting data within the context of a four-day statistical investigation. The investigation involved 26 children aged 5–6 years in interpreting and investigating a context of interest and relevance to them. The context involved decision making around the design of a zoo. We describe the repertoire of inscriptions that children used to track the appearance of zoo animals and explore their justifications for their invented inscriptions. The rationale for and genesis of inscriptions ranged from aesthetic considerations, ease and simplicity, to contextually driven decision making and approaches motivated by efficiency and by efforts to distinguish between repeated data values and different instances of the same attribute. We argue that when task interest is high the context provides affordances that support authentic data inquiry and data-based reasoning. Moreover, when the focus of the statistical investigation is on having children reason about and understand situations, what emerges are relatively sophisticated approaches to data inscription arising from efforts to make sense of and communicate statistical situations.

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6.1 Introduction

Most educators agree that young children start school with powerful mathematical ideas developed from informal experiences acquired in home and play settings. However, there is growing recognition that in order to maximize the mathematical development of young children we need to recognize the ways in which these preschool experiences contribute to their mathematical development. The field of statistics education has shown great promise in recognizing the nascent abilities of young children to engage in statistical thinking and reasoning through broadening what counts as evidence of statistical thinking in the early years. For example, recent studies of young children engaging in data handling activities have sought ways to create conditions in formal school settings to support and foster children's continued meaningful engagement in and development of statistical thinking (English, 2010, 2012; Kinnear, 2013; Leavy & Hourigan, 2018). Our study builds on previous research by exploring the knowledge and understandings that young children bring when collecting and tracking the appearance of data within the context of a data handling task. Specifically, we identify the different inscriptions or marks children use to record the appearance of data values and explore the justifications children provide for the decisions they make. Thus, we hope to address the concern of van Oers (2010) that 'not paying attention to these events (related to children's graphical marking) means that educators may neglect important and stimulating early events for the promotion of mathematical thinking' (p. 32).

6.2 Theoretical Perspective

6.2.1 *Representations in Early Childhood Mathematics*

There are many definitions of 'representation'. Most simply stated, a representation is something that stands for something else. In mathematics, representations can be thought of as *internal* or *external*. Internal representations are usually abstractions of mathematical ideas or internal cognitive schema that the learner creates. External representations take many forms such as verbal/gestural, enactive (manipulatives), visual/iconic (pictures, graphs) and symbolic/abstract (equations and formulas); these forms are external manifestations of concepts which communicate meaning and support the development of understanding. The process of concept development involves interaction between both internal and external representations which mutually reinforce, support and influence each other (Pape & Tchoshanov, 2001).

Perkins and Ungers (1994) define representations to mean 'symbols in any symbol system (formal notations, language, picturing, etc.) that serve to denote or exemplify' (p. 2). The important role of representations in the development of mathematical thinking is acknowledged in research and in national curriculum frameworks in many

countries. While earlier work in representations focused on college-level learners, there is growing awareness of the richness of young children's representations. Research indicates that the mathematical underpinnings and communicative function of early representations are often overlooked resulting in a missed opportunity for harnessing and promoting young children's emerging mathematical potential (Worthington & Carruthers, 2003; van Oers, 2010). This has led to interest in the representations young children make when moving from informal preschool mathematical experiences into the more formal abstract symbolism of school mathematics.

There is ample evidence that young children can understand one thing as representing another. Prior to entering school, children understand the representational qualities of pictures and video images (DeLoache, 2004) and by the age of four have constructed a wide range of inscriptional techniques (Karmiloff-Smith, 1992; diSessa, 2004). Much of the research on children's representations focuses on the graphic marks of very young children aged 0–3 (Lancaster, 2007) and on children's representations of number (Hughes 1986). A seminal study by Hughes (1986) explored the efforts of ninety-six children (ages 3–7) when asked to represent on paper the number of blocks on a table. Four different categories of responses emerged: idiosyncratic (lacking meaning), pictographic (representing the appearance of the blocks—shape/colour/orientation), iconic (discrete marks to represent blocks) and symbolic (conventional symbols). A larger study by Worthington and Carruthers (2003) of what they term the 'mathematical graphics' of 700 samples of young children's work resulted in the development of a taxonomy of mathematical graphics. This work extended that of Hughes (1986) to include two new categories of 'dynamic' and 'written'. Representations categorized as 'dynamic' capture some form of action and are used by children to represent quantities that are not counted. Representations categorized as 'written' refer to efforts to use words or letter type marks. The presence of a 'transitional period', which refers to representations that combine two categories of response, was also uncovered by Worthington and Carruthers (2003) and this period 'may be important as children move towards the abstract forms of mathematics'. The authors of both these studies argue that even in situations where the meaning of children's marks did not make sense to others, the marks have meaning for the children themselves and serve a communicative function. Indeed van Oers (2009) argues that a process of interactional construction of mathematical meaning between children and educators will 'finally yield meaningful mathematical symbols that may turn out to be more functional for the development of mathematical thinking than conventional symbols imposed onto the child's mind' (p. 33).

Research has uncovered factors which support the construction of representations. A Vygotskian view on early education emphasizes the critical role played by the educator in clarifying and interpreting children's marks and in promoting and stimulating meaning making (Vygotsky, 1978). Other factors include prior knowledge of the learner, the nature of the task, purpose for creating the representations, the learners' own internal representations of concepts (Pape & Tchoshanov, 2001), and the interaction of the learner with the social and material setting of the activity (Meira, 1995). Representations play an important role in the learning of mathematics, and it is important that students 'learn to use multiple forms of representation in com-

municating with one another' (Greeno & Hall, 1997, p. 363). While representations serve an important communicative role in the early years, their function is greater than that. Representations themselves serve as cognitive tools that help organize thinking, reduce demands on memory and cognitive load and support argumentation and discussion (Greeno & Hall, 1997; Pape & Tchoshanov, 2001).

6.2.2 Use of Representations in Statistics Education

Statistics education, as a discipline, has become more responsive to the challenges and pitfalls of introducing young learners to formal statistical symbolism, conventions and representations. We are now aware that a focus on teaching statistical procedures isolated from the broader view of the statistical inquiry leads to the absence of meaningful and connected understandings for learners.

Thus, what has emerged from recommendations and approaches to teaching school-level statistics is an awareness of the importance of opportunities to engage in a cycle of statistical investigation (Wild & Pfannkuch, 1999), and in particular, a focus on data modelling experiences for young children (Leavy, 2008). Studies have shown that in data modelling situations, when focusing on graphical representations, the task is to create a representation that reveals and displays patterns in the data. In these situations, children often created their own inscriptions or used and modified inscriptions with which they were already familiar such as letters, drawings, diagrams and symbols. In turn, the construction and use of inscriptions by children has led to the development of metarepresentational competence and knowledge relating to representations (Lehrer & Lesh, 2003; diSessa 2004; diSessa, Hammer, Sherin, & Kolpakowski, 1991). This work has been further facilitated by the development and use of technologies and software which have provided much of the needed support to authentically engage school-age children in the collection, management, representation and analysis of data (Ben-Zvi, Gil, & Apel, 2007; Hancock, Kaput & Goldsmith, 1992; Cobb, McClain & Gravemeijer, 2003; Papanistodemou & Meletiou-Mavrotheris, 2008).

However, engaging very young children in data modelling activities is challenging due to a variety of factors such as their limited ability to use technology, to work with large quantities (numbers) and to reason abstractly. Recent studies, however, which have incorporated design features specifically to support young children in data modelling, have shown great promise. In her study of the data modelling processes of six-year olds, English (2010, 2012) revealed how children's representations and inscriptions changed over time and reported on the metarepresentational competence displayed by children. When representing data, the majority of groups on their first effort constructed pictographs to communicate aspects of the data. When asked to consider whether their attributes and representations should be changed all but two groups, who moved from using pictograms to more formal bar graphs, continued to use pictograms. Interestingly, however, in response to this prompt they made one or more changes to their pictograms involving changes to inscriptions, paper

orientation, attributes, orientation of column/row data on the pictogram and used a mix of names and drawings. This and other studies indicate that young children have the ability to communicate data in appropriate representational forms (English 2010, 2012). However, there is evidence that some children tend to show a lack of awareness of the viewer in their selection of novel and esoteric design features and the concomitant neglect of design features that communicate meaning more clearly (Lehrer & Schauble, 2007).

These recent studies have provided critical insights into young children's statistical reasoning when engaged in core components of data modelling (English, 2010, 2012; Leavy & Hourigan, 2018), namely attribute selection, data representation and metarepresentational competence. Efforts to gauge the representational competence of children have focused primarily on children's inscriptions when constructing representations of data rather than the collection and tracking of data. The research reported in this chapter is an effort to address this gap by exploring children's representations in the very early stages of data modelling—when tracking and recording data.

6.3 Methodology

6.3.1 *Participants*

This study explores young children's (ages 5–6) approaches to collecting and representing data collected as part of a 4-day data modelling investigation. Participants were an intact multi-grade class of 26 primary school children. The 26 children engaged in four 60-min lessons focusing on data generation and collection, identification of attributes, structuring and representation of data and making informal inferences about the results. This chapter focuses on the outcomes of the first lesson which engaged children in generating and collecting data arising from a story context.

6.3.2 *Procedure*

The children were shown a purpose-made video of a fictitious zookeeper named Zach. Zach stated:

Hi everyone. My name is Zach and I wonder if you can help me today. I am designing a new zoo and I want to get some friendly animals for my zoo. But I am not sure which animals to pick. I need you to help me. I am going to read you a story 'A walk through the zoo'. It is about some pictures I took one day when I walked through a zoo. I want you to help me figure out which animals are the friendliest. I think the friendly animals are the ones that came out during my walk.

The pages of the story (and the associated images) were projected onto a large interactive whiteboard in the classroom. As the pages on the story changed, new animals appeared on screen. Each child was given responsibility for tracking the appearance of one specific animal during the story. Children were instructed to follow along as the teacher read the story and use their page to ‘make a mark’ whenever they saw their animal. Children were told that marks could take any form, and the teacher was careful not to provide any examples in case they influenced children’s approaches to mark making.

In order to aid memory, each child was given a blank page that had an image of their animal at the top of the page. Each child had the opportunity to track the data twice; this provided the opportunity to assess the stability of representations used by children across two data collection cycles (called cycles 1, 2). Cycle 1 was explained to children as an opportunity to ‘practice’; in cycle 2, children were assigned a different animal to track. At the completion of each cycle, in order to gain insight into the meanings attributed to their marks, children were questioned (based on a protocol of pre-designed questions) about their choice of mark(s).

We were interested in the approaches children took when provided with some ‘degree of freedom’ (van Oers, 2009) in their choices around tools and representations. Hence, rather than teaching the formal convention of tallying, we encouraged children to select their own representations to track the occurrence of data values.

6.3.3 Data Collection and Analysis

The lesson was designed by two teacher educators (authors of this chapter) in conjunction with five pre-service elementary teachers. It was the first of four lessons that engaged children in a cycle of statistical inquiry modelled broadly on the PPDAC cycle (Wild & Pfannkuch, 1999). Each pre-service teacher was assigned to a group of 5–6 children and took the role of ‘facilitator’ with their group. Their role was primarily to pose a selection of pre-designed questions in an effort to reveal children’s reasoning and justification for the selection of marks when collecting data. They did not provide any feedback or support in the selection of marks or in the decision making around the choice of marks made. Conversations within the groups were audio recorded and transcribed.

Data were analysed by both researchers, and the Worthington and Carruthers (2003) taxonomy of mathematical graphics was used to categorize responses as either dynamic, pictographic, iconic, written, symbolic or transitional. Drawing from the taxonomy, responses that captured some form of action were coded ‘dynamic’ and those that represented the appearance of the animal were identified as ‘pictographic’. The use of discrete marks was classified as ‘iconic’ (Figs. 6.1, 6.2, 6.3, 6.4, and 6.5) and the use of words/letters was considered ‘written’. The use of numbers was coded as ‘symbolic’ (Fig. 6.6), and responses that combined two categories of representations were identified as ‘transitional’ (Fig. 6.7a).

(a)



(b)



Fig. 6.1 a Use of checkmarks to represent patterns in the frequency of occurrence of data. b Use of tallies to represent patterns in the frequency of occurrence of data

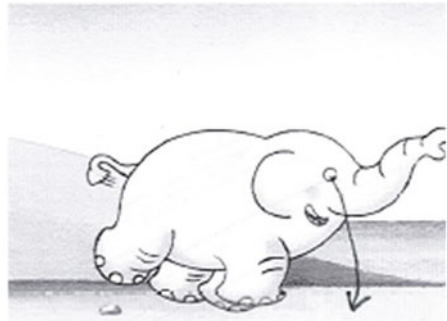


Fig. 6.2 Barbara's use of pictures of food to represent the occurrence of animals

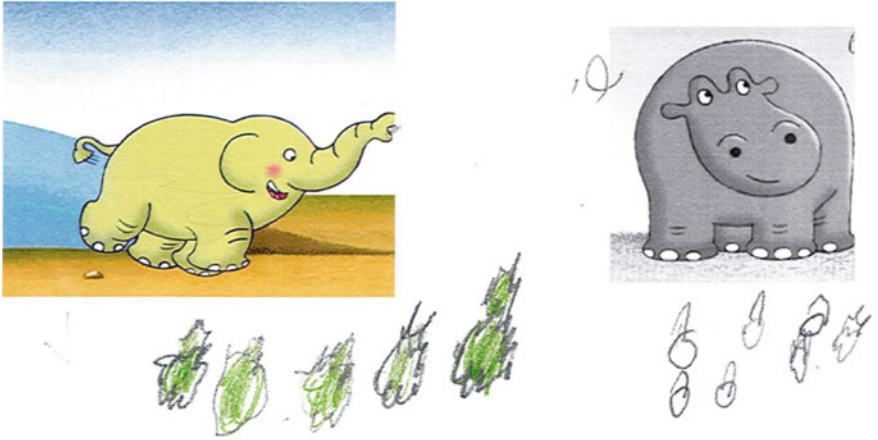


Fig. 6.3 Paul's use of pictures of food to represent the occurrence of animals

Fig. 6.4 Kate's use of different icons to facilitate accuracy in counting





000

Fig. 6.5 Polina's use of circles to represent (lack of) variability



1
2
3



12 3

Fig. 6.6 Use of numbers (symbols) to represent the occurrence of data

6.4 Findings and Discussion

The data examined the nature of the representations children used within and between cycles. Table 6.1 summarizes the categorization of responses during the first and second data cycles.

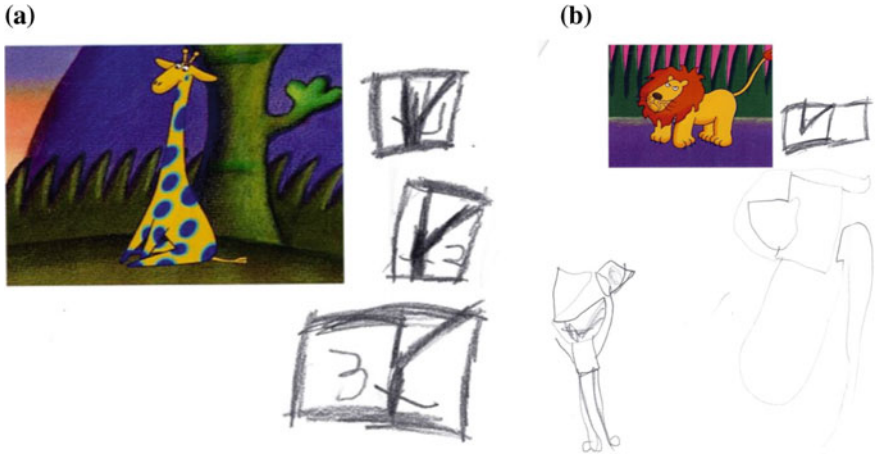


Fig. 6.7 **a** Transitional representation in cycle 1 of data collection. **b** Iconic representation in cycle 2 of data collection

Table 6.1 Classification of representations used to record data

Cycle	Dynamic	Pictographic	Iconic	Written	Symbolic	Transitional
#1			23		2	1
#2			23		3	

None of the approaches was classified as dynamic or pictographic. When asked about the meanings of the marks, analysis of the children’s responses indicated they understood that a mark symbolised the appearance of an animal.

Teacher	When you look at that mark you made Eva, what does it tell you?
Eva	It means I saw a lion.
Teacher	How many times did you see the elephant Laura?
Laura	3 times.
Teacher	How do you know?
Laura	Cause I can count the marks. They are kind of like circles. Look 1, 2, 3. 3 times.

6.4.1 Iconic Representations

The tendency of children to use iconic representations (Figs. 6.1, 6.2, 6.3, 6.4, and 6.5) to record data is evident from Table 6.1. During cycle 1, 23 children used marks that were categorized as iconic. These marks demonstrated an understanding of one-to-one correspondence as the child placed one mark each time the animal appeared. While the children used what Hughes (1986) refers to as ‘marks of their own devising’ (p. 58), there were some general patterns and trends in the types of marks they made. The researchers further classified iconic representations as: tallies, check marks and pictures. The latter of these iconic representations, pictures, were classified as discrete images/illustrations that were drawn to index each occurrence of the appearance of an animal (see Figs. 6.2 and 6.3). While tallying, check marks and pictures were equally prevalent in cycle 1, the second cycle brought about changes in the types of iconic representations children used (Table 6.2).

6.4.1.1 Tallying and Checkmarks

The use of *checkmarks* was very prevalent and accounted for 33% ($n = 8$) of responses initially and dropped to 12% ($n = 4$) on the second data collection round (Fig. 6.1a). With the exception of two children, checkmarks were recorded in a horizontal line. Responses that resembled the traditional convention of *tallying*, consisting of vertical lines to represent the occurrence of each value, were classified as belonging to this category (Fig. 6.1b). None of the children grouped the tallies in groups of 5 through the conventional use of a diagonal line. In cycle 1, tallying was very common and accounted for 33% of responses. While on almost all occasions tallies were recorded in a horizontal line, Cornelia, organized her tallies vertically down the page during both cycles of data collection. The prevalence of tallying decreased significantly in cycle 2, and it became the least prevalent approach used by 8% ($n = 2$) of children.

When asked to explain why they used tallies and checkmarks, many of the responses related to ease and simplicity. Justifications for using tallies were ‘they are easy to make and easy to count at the end’ (Tomi) and ‘they are nice and tidy’ (Ayesha). Similarly, checkmarks were described as ‘simple to do’ (Sheena) and ‘easy to count’ (Mia). In the following conversation with Matthew he was asked why he used tallies during both cycles of data collection.

Table 6.2 Types of iconic marks used across both data cycles

	Cycle #1	Cycle #2
Tallies	8	2
Checkmarks	8	3
Pictures	7	14

Teacher	Matthew, you used these same marks for when you saw the hippo and the elephant. Can you tell me about the marks?
Matthew	They are lines.
Teacher	Why did you pick lines?
Matthew	Lines make me count properly and help me.

6.4.1.2 Pictures

The pictures drawn by children were categorized as iconic as each image represented the occurrence of one data value/event. Thus, pictures in this study differ from the categorization of marks identified as ‘pictographic’ used by Hughes (1986) and Worthington and Carruthers (2003). In the aforementioned studies, the picture was merely a rendering of the object in front of the children, whereas in our study, each picture was drawn to represent a reoccurrence of the data value (i.e. the animal being tracked) and is more akin to an ‘illustrative tally mark’.

The use of pictures was particularly interesting for a number of reasons. Firstly, the influence of the task (counting the appearance of animals) and the image colour was evident in the pictures. Both Paul and Barbara made marks to represent the food their selected animal ate. In cycle 1, Barbara tracked the appearance of the giraffe and drew bananas to represent the frequencies (Fig. 6.2). When asked why she chose bananas, she stated ‘giraffes like bananas as much as monkeys do. And giraffes are yellow like bananas’. During cycle 2, she tracked the elephant and drew peanuts as her marks (Fig. 6.2) and justified it as ‘I’ll draw nuts to feed the elephant’. Similarly, Paul appeared to be influenced by both the context (animals) and the colour. On both occasions, he drew pears to feed the elephant and hippo. During cycle 1, he had a colour copy and his selection of pear was influenced by the colour as he said ‘Well the elephant is green in this picture and pears are green’. However, on the second occasion he had a black and white picture of a hippo and he selected a pencil to draw black pears (Fig. 6.3).

Analysis of conversations with children revealed that in a small number of cases ($n = 5$) pictures were used to distinguish *ordinality* and facilitate *accuracy in counting*. While in most situations, the pictures drawn were the same for each occurrence (a banana or peanut each time, Fig. 6.2), there were five occasions where children chose to represent each occurrence of an animal with a different mark. The following excerpts provide insights into the children’s reasoning.

Hence, we can see that for Laura the different marks could also be used to register the *ordinality of the event*, whereas for Kate it facilitated *accuracy in counting* (Fig. 6.4). For some children, the reason was aesthetic as is evident in Mia’s response justifying why she drew different pictures for each data value as ‘I wanted to make a design’.

Teacher	What marks did you make Kate?
Kate	I used a happy face, love hearts, stars and triangles.
Teacher	And why did you make all different marks?
Kate	So when I count them, I know I counted one and I won't count it again. I count them better.
Teacher	Tell me about your marks Laura. Why are they different?
Laura	They are all different sizes. And they remind me of when I saw the animal.
Teacher	What do you mean?
Laura	Well that one [pointing to one mark] was the last time I saw him.

6.4.2 *Changes in Use of Iconic Representations Across Data Cycles*

The use of pictures as a method to record data became more prevalent in cycle 2 (see Table 6.2). Six children who used pictures in cycle 1 continued to use pictures in cycle 2 and two changed to using tallies. However, eleven children who used tallying and check marks in cycle 1 changed to using pictures in cycle 2.

Analysis of the data showed that clusters of children who sat together in groups moved from using tallies and checkmarks to using pictures; hence, there may have been a *social effect*. Some of these children appeared to have observed and been influenced by the pictures a child in their group had drawn in cycle 1. For example, Leah was in the same group as Paul and Barbara (Figs. 6.2, and 6.3); she had used check marks in cycle 1 and moved to using tufts of grass in cycle 2. She explained her use of grass because 'he looks really sad, I wanted to give the lion some grass to eat'. Another group of children who were sitting together (Tomi, Caitlyn, Hannah) had all used tallies in cycle 1 and changed to using pictures (hearts and stars) in cycle 2. This move to the use of pictures may also be attributed to these young children's focus on the *aesthetic* dimensions of their work. Several children were asked to explain why they changed their marks to pictures during cycle 2, and they explained 'to make it look better' (Sian), 'it looked good' (Kate) and 'to make the page look nice' (Darren). It is important to note that while the type of icon changed, the function remained the same.

6.4.3 *Efforts to Convey Meaning in Iconic Representations*

In five instances, the marks used were intended to convey information beyond frequencies of occurrence of data values. These efforts were quite sophisticated and appeared to arise out of effort to communicate information relevant to the task context.

Polina used a series of small circles to represent the occurrence of her animal. She stated ‘they are all circles. They are the same size so we would know we are still counting the same animal’. Hence, the circles represented the frequency of occurrence but also had the potential to *record variability* in data values using size as an indicator (Fig. 6.5).

There were some examples of interesting strategies used when collecting data on monkeys. With the exception of the monkeys who appeared in *pairs on 5 occasions*, there was never more than one of the same animal appearing on any one page of the story. Five children recorded the monkeys, and two of these, Darren and Aidan, made efforts to differentiate between occasions where just one monkey appeared and occasions when two appeared together. Darren used a tally mark when there was just one monkey and an apple when the second monkey occurred in close proximity to the other (Fig. 6.1a). He explained it as ‘Every time I saw a monkey I used a tick but I drew an apple when the monkey had a friend’. Darren correctly recorded 2 of the 5 occasions when both monkeys appeared together. Aidan used a different strategy and referred to the fact that monkeys appeared in pairs and tried to have his ‘lines’ appear in groups of two—hence physical proximity of the tallies was used to communicate pairs. He said ‘I always get them in pairs’, and ‘the animals come in 2 s’ (Fig. 6.1b).

6.4.4 *Symbolic Representations*

A small number of children favoured the use of numerals as a strategy to record data; their justifications were based on ease of use and efficiency. Peter stated that he used numbers because ‘it would be easier to see what you have’ (Fig. 6.6). Sian made an implicit reference to cardinality when she said she used numbers because ‘I don’t have to count how much the giraffe came up. I just see the last number and that’s the answer’ (Fig. 6.6).

6.4.5 *Changes in Representations*

As there were two data collection cycles, it provided an opportunity to explore the stability of representations used by children. Table 6.3 reveals that 20 children used the same type of representation across cycles 1 and 2. One child used symbolic representations in both cycles, and 19 used iconic representations across both cycles.

Table 6.3 Changes in strategy across events

No change in representation	Iconic -> Iconic	19
	Symbolic -> Symbolic	1
Change in representation	Iconic -> symbolic	2
	Transitional -> Iconic	1

However, as discussed in the previous section, there was movement between the different types of iconic representation used in both cycles. Four children showed movement between representations. Two moved from iconic to symbolic, one from symbolic to iconic and one children who was identified as transitional used an iconic representation on the second cycle.

As mentioned in the previous section, one child was classified as transitional during cycle 1. During the first cycle, he used a combination of check marks and symbols to track the appearance of the giraffe thereby combining aspects of more than one category of response (Fig. 6.7a). This was a relatively complex response, which suggests he was moving from iconic towards more symbolic and abstract representation forms. It was somewhat a surprise then, when during the second cycle he used marks classified as iconic and no longer used symbols. Examination of Fig. 6.7b reveals the use of three very different and somewhat complex images, to represent the appearance of the lion, and no effort to use symbolic forms. One possibility to account for the change in approach is that he may have been influenced by other children in the group, the majority of whom drew pictures in cycle 2.

6.4.6 Reasoning About the Context

As children were looking at the data and tracking the appearance of animals, they were engaged in thinking about the driving question which motivated the data collection, i.e. What animals are friendliest? When discussing the friendliest animals, while not required to do so, they frequently referred to factors that may have influenced the frequency of appearance of different animals. Some of these factors were contextual and based on knowledge of the animal kingdom. Knowledge of the contexts within which problems are set was also found to be a support for 6-year old children in the research described by Jane Watson in Chap. 4 of this book. In her chapter, Watson reports that when the data were presented in familiar contexts (such as lollipops and books), as compared to less familiar contexts (weather in this case), that it influenced children's ability to comprehend the questions asked. To take one example from our research in this chapter, children were very eager to discuss why the lion appeared only 3 times; the following statements point to the importance of the context in supporting children's reasoning.

Other suggestions to account for the frequency of appearance of animals were based on patterns that were observed within the data. For example, in reference to

Peter	The lion must be minding her babies, that's why we only saw her 3 times.
Melios	He must be hibernating.
Cornelia	The lion wasn't here much. He is afraid of people.
Kate	I only saw the lion 3 times. He's asleep.

the monkeys, Polina explained the high frequency of appearance as 'because there's two monkeys in each picture—when it shows one monkey there's another monkey next to it'.

6.5 Conclusion

This study reveals insights into the inscriptions young children make when collecting data in a data-modelling environment. Conversations with children around their choice of inscriptions uncovered the multiple meanings they incorporate into the marks they make. Analysis of the data confirmed that once the child embarks on making marks, these marks become both a record of and an abstraction for the real event. For these children, the marks stimulate an image of and support recall of the event that motivated the collection of data. In this way, this study supports the finding of van Oers (2010) that for young children inscriptions serve a communicative function and represent the beginnings of abstract thought. Thus, we argue that when the focus of the statistical investigation is on having children reason about and understand situations, what emerges are relatively sophisticated approaches to data inscription arising from efforts to make sense of and communicate statistical situations.

Children's justifications for inscriptions ranged from aesthetic considerations, ease and simplicity, to contextually driven decision-making and approaches motivated by efficiency and by efforts to distinguish between repeated data values and different instances of the same attribute. These explanations indicate that their representations were more than a record of frequencies and served in some cases as cognitive tools (Greeno & Hall, 1997; Pape & Tchoshanov, 2001) to help organize thinking. This was evident in Laura's efforts, which she justified as keeping an account of ordinality, in Polina's use of same-sized circles to communicate variability and in the efforts of both Darren and Aidan to convey the structure of the data. The variety of approaches used to index and describe the data may be an indicator of the meaningfulness of the task; this influence of the task context on the creation of meaningful representations has also been a finding of other studies (Vellom & Pape, 2000). The levels of interest displayed by the children in the task (recording the appearance of animals) and the larger context (the zoo), we believe, provided affordances that supported these young learners in authentic data inquiry and in data-based

reasoning. Children were motivated and on-task throughout the activity and eagerly discussed reasons for the different frequency of occurrences of animals. Thus, the context both maintained interest and in some cases informed the choice of representations to use when collecting data. This critical role played by context was also a feature in data modelling studies with young children using story (English, 2010, 2012; Hourigan & Leavy, 2016; Kinnear, 2013) and technology (Paparistodemou & Meletiou-Mavrotheris, 2008).

The large repertoire of inscriptions used by children were similar to those identified by Hughes (1986) and Worthington and Carruthers (2003). The absence of responses categorized as dynamic or pictographic attests to the understanding on the part of the children that the inscription was an abstraction of the real event, i.e. represented the occurrence of a specified data value. Iconic inscriptions were by far the most popular approach to record data. Understandings of one-to-one correspondence and the consideration of frequencies were apparent in inscriptions classified as iconic. The stability of iconic responses across both tasks was indicative of children of this age and also resulted in accurate recording of the occurrence of data values. While the absence of formal tallying (in groups of 5) was not surprising as it is a school mathematics practice, the abundance of informal tallies ties in with other studies where tally marks appear very frequently in the spontaneous representations of children as young as 3 and 4 years old (Hughes, 1986; Lehrer & Schauble, 2000). The relationship between tallies and finger counting, evidenced in the accounts reported by historians of mathematics, may account for the prevalence of informal tallies. Indeed, Hughes (1986) following an overview of the written number systems of other cultures refers to the 'extremely fundamental nature of tallying' (p. 83) over thousands of years.

An interesting, and somewhat unexpected finding, was the fluidity in the types of iconic responses used across both cycles of data collection. Children moved between tallies, check marks and pictures to record events and were influenced by the efforts of others. In particular, there was a move to using pictures to record data in the second cycle of data collection; this did not reduce the accuracy of children's responses. This change in representation may have been motivated by the possibilities to use colour and the aesthetic dimensions of the work. Alternatively, as this was their second effort at collecting data, the children may have had more cognitive resources available to them during the second cycle thus enabling them to concentrate on the construction of pictures. The absence of a transitional period wherein children's inscriptions combine aspects from more than one category of response distinguishes these findings from those of Worthington and Carruthers (2003). This may be due to the similarity in ages of the children in this study as compared to the research by Worthington and Carruthers (2003) which looked at children across a wide span of ages.

While the constructions of representations within the context of data collection serves a more confined purpose than representation use in later years' mathematics; these representations are important nonetheless. They form a communicative role (Greeno & Hall, 1997) in conveying the frequency of occurrence of a data value. Moreover, they serve as antecedents to more formal and standard representational forms for which children will later have to negotiate meaning

(diSessa et al., 1991). When we open up opportunities for young children to participate in statistical activities in ways that make sense to them, we provide opportunities for children themselves to construct meaning and promote genuine developmentally appropriate learning. The representations produced by the young children in this study attest to the quality of their participation in the data modelling environment.

The research has a number of limitations. Firstly, this is a case study of one class of 5–6-year olds; hence, the results of this study cannot be generalized to all children of this age. However, there is potential for further study to examine additional age groups in a variety of educational settings. The second limitation relates to the relatively short time the children engaged with the task. The extension of the study over a longer duration would facilitate more thorough analysis and reap interesting findings where the nature of children's inscriptions could be tracked over a number of years.

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