Chapter 5
Transition to School: Prior to School Mathematical Skills and Knowledge of Low-Achieving Children at the End of Grade 1

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Abstract Recent psychological studies as well as research findings in mathematics education highlight the significance of early number skills for the child's achievement in mathematics at the end of primary school. In this context, the ongoing 3-year longitudinal study discussed in this chapter, investigates the development of early numeracy understanding of 408 children from 1 year prior to school until the end of Grade 1. The study seeks to identify children who struggle with respect to their mathematics learning after the first year of school and compare their achievements with their number concept development 1 year prior to school as well as immediately prior to school entry (Grade 1). Initial findings suggest that children's understanding and skills with respect to number and counting are important precursors for later school success. The children who were identified as low-achievers in mathematics at the end of Grade 1, also demonstrated less knowledge and skills than their peers prior to school.

5.1 Introduction

Children start developing mathematical knowledge and abilities a long time before they enter formal education (Anderson et al. 2008 ; Ginsburg et al. 1999). In their play, their everyday life experiences at home and in child care centres they develop a foundation of skills, concepts and understandings about numbers and mathematics (Anderson et al. 2008; Baroody and Wilkins 1999). However, the range of mathematical competencies children develop prior to school obviously varies quite substantially. While most preschoolers manage to develop a wide range of informal knowledge and skills in early numeracy, there is a small number of children who, for various reasons, struggle with the acquisition of number-skills (Clarke et al. 2008; Peter-Koop and Grüßing 2014). Furthermore, clinical psychological studies suggest

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B. Perry et al. (eds.), *Mathematics and Transition to School,* Early Mathematics Learning and Development, DOI 10.1007/978-981-287-215-9_5

that children potentially at risk in learning mathematics can already be identified 1 year prior to school entry by assessing their number concept development (Aunola et al. 2004; Krajewski 2005). Findings from these studies also indicate that these children benefit from an early intervention prior to school helping them to develop a foundation of knowledge and skills for successful school-based mathematics learning. This seems to be of crucial importance as findings from the SCHOLASTIK project (Weinert and Helmke 1997) suggest that students who are low achieving in mathematics at the beginning of primary school tend to stay in this position. In most cases a recovery does not occur. In addition, Stern (1997) emphasises that subject-specific knowledge prior to school is more important for later success at school than general cognitive factors such as intelligence. Hence, the development of early numeracy skills should be included in early childhood education prior to school entry in kindergarten or preschool programs.

5.2 Theories on Number Concept Development

While pre-number activities based on Piaget's *logical foundations model* are frequently still current practice in first year school mathematics (Anderson et al. 2008), research findings as well as curriculum documents increasingly stress the importance of children's early engagement with sets, numbers and counting activities for their number concept development. Clements (1984) classified alternative models for number concept development that deliberately included early counting skills (Resnick 1983) as *skills integrations models*. Piaget (1952) assumed that the development of number concept builds on logical operations based on pre-number activities such as classification, seriation and number conservation. He emphasised that the understanding of number is dependent on operational competencies. In his view, counting exercises do not have operational value and hence no conducive effect on conceptual competence regarding number. However, since the late 1970s this theory has been questioned due to research evidence suggesting that the development of number skills and concepts results from the integration of number skills, such as counting, subitising and comparing (Fuson et al. 1983, Clements 1984; Sophian 1995).

Krajewski and Schneider (2009) provide a theoretical model that is based on the assumption that the linkage of imprecise nonverbal quantity concepts with the ability to count forms the foundation for understanding several major principles of the number system. The model depicts how early mathematical competencies are acquired via three developmental levels (see Fig. 5.1). In the *first level* (basic numerical skills) number words and number-word sequences are isolated from quantities. In the sense of Resnick's "proto-quantitative comparison schema" (1989, p. 163) children compare quantities without counting by using words like 'less', 'more' or 'the same amount'. At the age of 3–4 years most children start to link number words to quantities, i.e. they develop awareness of numerical quantity (Dehane 1992) and hence enter the *second level* (quantity number concept). The understanding of the linkage between quantities and number words is acquired in two phases:

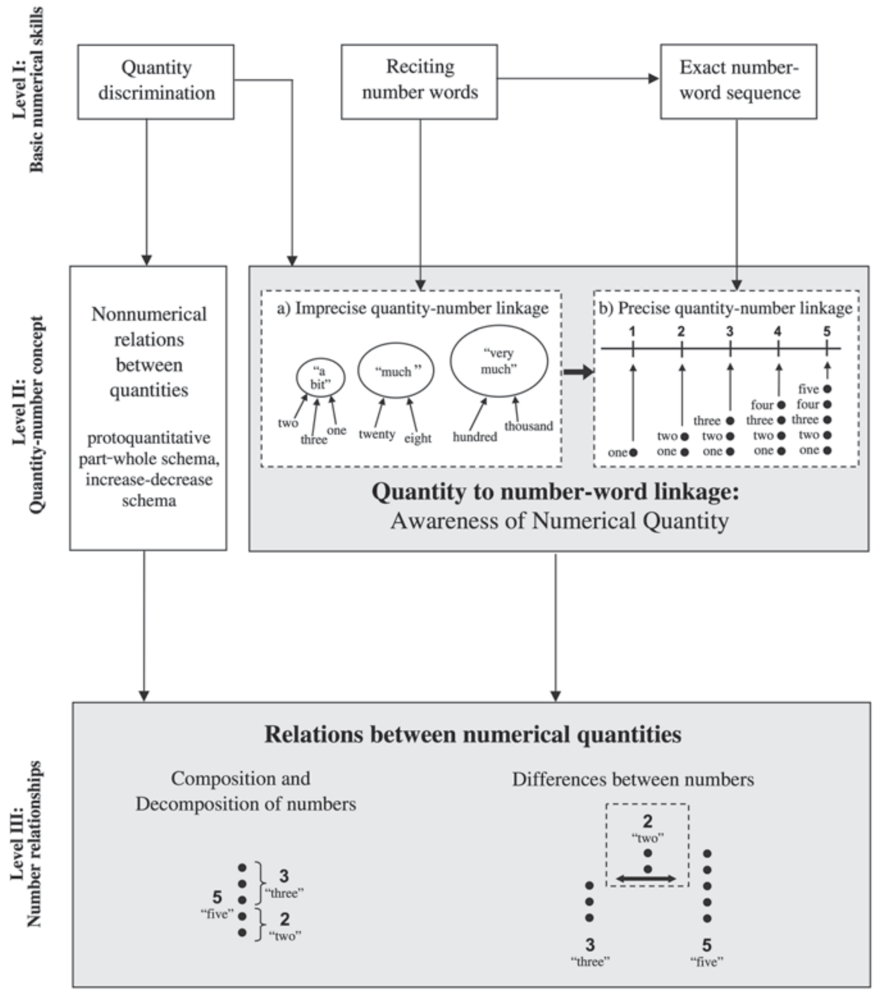

Fig. 5.1 Model of early mathematical development. (Krajewski and Schneider 2009, p. 515)

> First they develop an imprecise, vague conception of the attribution of number words to quantities and assign number words to rough quantity categories (Level IIa: imprecise quantity to number-word linkage)…. The ability to distinguish close number words develops in the second phase of the quantity to number-word linkage, when number words are also linked to exact quantities (Level IIb: precise quantity to number-word linkage, where counting is linked with quantity discrimination). (Krajewski and Schneider 2009, p. 514)

Furthermore, at this level children also gain experiences with non-numerical relations between quantities as they increasingly understand "proto-quantitative part-whole schema", i.e. the understanding that a quantity can be split into pieces which, taken together, make up the whole quantity, as well as "proto-quantitative increase/decrease schema", i.e. the insight that quantities change if something is taken away or added (Resnick 1989, p. 163).

At the *third level* (linking quantity relations with number words) children then understand “that the relationship between quantities also takes on a number-word reference. They realise that numerically indeterminate quantities, e.g., “all” lollies, can be divided into smaller amounts, e.g., “a few” lollies, and “also understand that this can also be represented with precise numbers” (Krajewski and Schneider 2009, p. 516), e.g., five lollies can be split into two lollies and three lollies, which then again make five altogether. Fuson (1988) described this as *composition* and *decomposition* of numbers. Furthermore, children discover that two numerical quantities (e.g., three lollies and five lollies) differ by a third numerical quantity (two lollies).

However, it is important to note that children are not necessarily at the same developmental stage with respect to number words and number symbols. Furthermore, a child might have already reached the third level when dealing with smaller numbers, while s/he still operates with larger numbers on the second level. The use of manipulatives also affects the children’s performances, so that a child might already reach the second or third level when using concrete objects, while still not able to deal with tasks based on iconic or symbolic representations. Hence, with respect to numerical development, it is very difficult to classify a child exactly to one level (Krajewski et al. 2009).

In summary, Krajewski (2008) states that the quantity-number-competencies that children develop up to school entry build the foundations for later understanding of school mathematics. While competencies on the third level (i.e. number relationships) reflect first computation skills and in this respect initial arithmetic understanding, the first two levels (i.e. basic numerical skills/ quantity-number concept) can be accounted as “preparatory mathematical skills” (pp. 208–281).

5.3 Number-Quantity Competencies and their Influence on the Transition to School Mathematics

In a longitudinal study Krajewski and Schneider (2009) investigated the predictive validity of the quantity-number competencies of these developmental levels for mathematical school achievement. The results of the studies indicate that quantity-number competencies related to the *second level* (see Fig. 5.1) measured in kindergarten predict about 25 % of the variance in mathematical school achievement at the end of grade 4. Moreover, a subgroup analysis indicated that low-performing fourth graders had already shown large deficits in their early quantity-number competencies (p. 523). It can be concluded that these early quantity-number competencies constitute an important prerequisite for the understanding of school mathematics. These results conform to other longitudinal studies (Aunola et al. 2004, Kaufmann 2003).

Furthermore, a previous intervention study by the first author in 2005–2008 indicates that (at least in Germany) children with a migration background[1] are overrepresented in the group of preschoolers potentially at risk in learning school mathematics (Grüßing and Peter-Koop 2008; Peter-Koop and Grüßing 2014; Peter-Koop et al. 2008). A total

[1] Migration background in this context means that the children speak at least one language other than German at home.

of 854 children were interviewed/tested 1 year prior to school with three different instruments—an early numeracy interview, a standardised test as well as an intelligence test for preschoolers and the individual results led to the identification of 73 children potentially at risk in learning school mathematics based on the current stage of their number concept development. Following an 8 months long, primarily play-based, intervention (for details see Peter-Koop and Grüßing 2014, pp. 311–313) all participants of the study were interviewed/tested again immediately before entering Grade 1. In order to monitor long-term effects of the intervention, follow-up tests were conducted at the end of Grade 1 and Grade 2. The intervention for the 73 preschoolers identified to be potentially at risk learning school mathematics was conducted in two treatment groups: Children in group 1 were visited weekly by a pre-service teacher who had been prepared for this intervention as part of a university methods course. The intervention for the children in group 2 in contrast was conducted by the kindergarten teachers. While the intervention for group 1 was carried out one-on-one at a set time each week, the kindergarten teachers working with the children in group 2 primarily tried to use every day related mathematical situations, focussing on aspects such as ordering, one-to-one correspondence or counting, as they arose in the children's play or everyday routine. In particular, they challenged the children identified to be at risk in these areas. Children in both groups were not aware of the fact that they took part in an intervention. However, the parents of all children who took part in the intervention had been informed and had given their written permission. It is important to note that for ethical reasons it was not possible to establish a control group, i.e. children identified to be potentially at risk who did not receive special support prior to school, as parents would not have agreed for their children to be part of this group.

Key results of the study can be summarised as follows (Peter-Koop and Grüßing 2014):

- The data clearly show short-term effects of the intervention. The children potentially at risk in particular have increased their competencies in those areas that were addressed during the intervention, i.e. knowledge about numbers and sets as well as counting abilities, and performed significantly better in the post-test, especially in tasks related to ordinal numbers, matching numerals to dots, ordering numbers, knowing numbers before/after and part-part-whole relationships (p. 314).
- With respect to the substantial increase in achievement demonstrated by the children of the two intervention groups, no significant difference between the group of children who experienced a weekly one-on-one intervention and the group of children who received remedial action within their groups was found (p. 316).
- While children with a migration background were over-represented in the group of preschoolers who were identified as at risk with respect to learning school mathematics (see above), this group also demonstrated the highest increase in mathematical achievement in the test interval. While the achievement of both groups, i.e. migrant children and children with a German speaking background increased ($p < 0.001$) within the test interval, the children with migration background demonstrated an increase of 3.6 points between pre- and post-test compared to an increase of 2.9 points in the remaining group of children from German families (p. 315).

- Further analyses of data collected at the end of Grade 1 and Grade 2 suggest that for more than 50 % of the children from the two treatment groups the increase in their mathematical achievement prior to school entry proves to be of lasting effect at the end of Grade 1 (Grüßing and Peter-Koop 2008, pp. 77–78). However, this percentage drops significantly after year 2 (Peter-Koop and Grüßing 2014, p. 317). One possible explanation for this finding relates to curriculum. In Grade 2 mathematics in Germany the focus shifts from number work to operations—a concept area that was not included in the intervention.

While overall the results of the intervention study are encouraging, there are a number of questions that cannot be addressed on the basis of the data collected. Since the study lacks a control group (see above), it is not clear how many of the children identified to be potentially at risk learning school mathematics based on their number concept development 1 year prior to school would have shown at least average achievement at the end of Grade 1 without participating in the intervention. In order to optimise early intervention for children at risk, it is necessary to understand which of the skills contributing to children's number concept development and counting, the children who are low achieving in mathematics at the end of Grade 1 particularly struggle with before school entry in comparison to their higher achieving peers. Research suggests that knowledge and skills with respect to number word sequences, subitising and part-whole understanding are key predictors for the identification of children with dyscalculia[2] in Grade 1 or Grade 2 (Dornheim 2008).

Considering the findings from the SCHOLASTIK project (Weinert and Helmke 1997) indicating that low achievers in mathematics at the beginning of primary school in general tend to stay in this position, an early intervention for these children seems to be of crucial importance. Hence, a screening instrument to be applied 1 year prior to school would help to identify those children who should receive special support prior to school entry, i.e. Grade 1. In this context, the OTZ, i.e. the standardised test used in the study, proved to be very difficult for non-German speaking background children due to its demands on German language comprehension. The data from the 2005–2008 study suggests that the EMBI-KiGa (see methodology) is a suitable instrument for the collection of information on preschoolers' individual number learning and respective identification of children that need special support.

These aspects are addressed in a recent longitudinal study (2011–2014) using the same instruments and the same measuring points (1 year prior to school, immediately before school entry, at the end of Grade 1 and at the end of Grade 2) as in the previous study, while the focus of this new study is different. It is recursive in nature, which means that rather than identifying children potentially at risk learning mathematics 1 year prior to school, the lower-achieving learners at the end of Grade 1 are identified[3]. For these children the longitudinal data from two previous measuring points will be analysed to investigate whether these children already showed

[2] However, it is important to note that not all arithmetic learning difficulties can be put on a level with dyscalculia.

[3] A fourth measuring point was included in order to acknowledge the fact that the group of low-achieving children might change towards the end of junior primary school, i.e. that children who

less knowledge with respect to numbers, quantities and counting than did their more successful peers in Grade 1 and if this is the case, to identify the areas that these children—in contrast to their peers—struggled with prior to school.

Furthermore, the new study seeks to validate the EMBI-KiGa as a suitable screening instrument as well as use data from the first measuring point to match profiles of children at risk from the first study and to create a control group of children who did not receive any intervention prior to school and compare their development with children from the intervention group. However, this paper will focus on the identification of low achievers at the end of Grade 1 and address the following research questions:

1. Which children have clearly below average achievement at the end of Grade 1 with respect to their early numeracy skills?
2. Which content areas do these children struggle with most?
3. What number-quantity competencies did these children demonstrate 1 year prior to school and immediately before school entry?
4. Which content areas did they struggle most with before school entry?

5.4 Methodology

The data collection involves four measuring points MP1–MP4 (an overview about the design of the study is provided in Table 5.1). During each measuring point all children participating in the study were given a standardised test on number concept development suitable for their respective age as well as a task-based interview. For the two measuring points prior to school entry (MP1 and MP2) the following two instruments were used, with each individual interview lasting 15–30 min.

- the German version of the *Utrecht Early Numeracy Test* (OTZ; van Luit et al. 2001)—a standardised individual test in interview form aiming to measure children‘s number concept development that involves logical operations based tasks as well as counting related items,
- the *Elementarmathematisches Basisinterview* for use in kindergarten (EMBI-KiGa) based on the *First Year at School Mathematics Interview* (FYSMI)[4] developed in the context of the Australian *Early Numeracy Research Project* (Clarke et al. 2006)—a task-based one-on-one interview for 5-year-olds allowing children to articulate their developing mathematical understanding through the use of specific materials provided for each task, which has been published by Peter-Koop

show slower (mathematical) development than the majority of their peers might perform more weakly at the end of Grade 1 than at the end of Grade 2.

[4] The FYSMI is conducted in the first year of school, which in Australia is the preparatory grade preceding Grade 1. This preparatory year is compulsory and children are aged between 4 years 9 months and 6 years. In Germany in contrast, formal schooling starts with Grade 1 when children are 6 years old. While the vast majority of German five-year-olds attend kindergarten, this is not compulsory and involves fees to be paid by the parents.

Table 5.1 Measuring points, instruments and participants of the study

Measuring points	Instruments	Participants	Ages of the participants (years)
June 2011 MP 1	OTZ	Children participating in the study ($n=538$)	4–5
	EMBI-KiGa	Children participating in the study ($n=538$)	
June 2012 MP 2	OTZ	Children participating in the study ($n=495$)	5–6
	EMBI-Kiga	Children participating in the study ($n=495$)	
June 2013 MP 3	DEMAT 1+	All grade 1 classes with children participating in the study ($n=2250$)	6–7
	EMBI	Children participating in the study ($n=408$)	
June 2014 MP 4	DEMAT 2+	All grade 2 classes with children participating in the study	7–8
(to be conducted)	EMBI	Children participating in the study	

and Grüßing (2011) while the original Australian document is published by the Department of Education, Employment and Training (DEET) (2001).

Data on student achievement in mathematics after the first and second year of primary school is collected with the following instruments:

- *Deutsche Mathematiktests für 1. und 2. Klassen* (DEMAT 1+; Krajewski et al. 2002/DEMAT 2+; Krajewski et al. 2004)—German curriculum based standardised paper and pencil tests conducted at the end of the school year with the whole class.
- *Elementarmathematisches Basisinterview Zahlen und Operationen* (EMBI; Peter-Koop et al. 2007)—a task- and material-based one-on-one interview assessing children's developing mathematical understanding in the four areas counting, place value, addition/subtraction strategies, multiplication/division strategies[5].

The data reported in this chapter only involve the first three measuring points while the third measuring point is the basis for the following analyses. Since the study aims to monitor long-term development, a fourth measuring point at the end of Grade 2 is planned in order to investigate whether the group of low achievers identified at the end of Grade 1 is still low achieving at the end of Grade 2 or whether the number of children low achieving in school mathematics will increase or decrease and with which areas they are (still) struggling. Furthermore, this paper only focuses on the

[5] This instrument is a German adaptation of the Australian Early Years Interview (Department of Education, Employment and Training 2001).

children participating in all three measuring points ($n=408$). At this point the analysis of the data from the DEMAT 1+, i.e. additional data from all Grade 1 classes with children participating in the study ($n=1842$), is still in progress. The analysis aims to specify and diminish possible intra- and inter-group effects related to mathematics instruction in Grade 1. Hence, this information cannot be included in this paper.

For a total of 408 children (206 male, 202 female), complete data sets from the first three measuring points are available[6]. Concerning the migration background of the children, the sample includes 193 children (47.3 %) with and 215 children (52.7 %) without a migration background. This set of data provided the basis of the quantitative analysis with the use of SPSS.

In order to identify low achieving children at the end of Grade 1 based on their performances in the EMBI, the growth points[7] that are used to describe student achievement were translated into number scores counting one point for each growth points > 0 in each of the four interview parts—A: Counting, B: Place Value, C: Strategies for Addition and Subtraction, D: Strategies for Multiplication and Division. Based on this scoring the maximum number of points is 23.

5.5 Results

In the following section key results of the first three measuring points MP 1 to MP 3 of the study will be presented with respect to the four research questions guiding the study. However, it is important to note that more detailed and complex analyses will be conducted after the completion of the data collection in 2014.

5.5.1 Identification of Low-Achieving Children in the Sample

In order to identify the children in the sample who are low achieving in mathematics at the end of Grade 1 a cross mapping of the results in the DEMAT 1+ and EMBI

[6] In order to base the statistical analyses on a complete and coherent data set, all student data that was incomplete with the respect to all measuring points or clearly incorrect due to mistakes during the data collection and recording were omitted.

[7] The framework of "growth points" reflects the analysis of "available research on key stages of levels in young children's mathematics learning, as well as frameworks developed by other authors and groups to describe learning" (Clarke et al. 2002, p. 12). The framework was developed to describe mathematical growth of children from 5 to 8 years of age. According to the ENRP researchers "growth points can be considered primary stepping stones along the way to understanding important mathematical ideas" (Clarke et al. 2003, p. 69). To illustrate this concept, the growth point descriptors for counting (interview part A) are given below (Clarke et al. 2002, p. 124).

A. Counting: 0. Not apparent; 1. Rote counting; 2. Counting collections up to 20 objects; 3. Counting by 1 s (forward/backward from variable starting points between 1 and 100; knows numbers before/after); 4. Counting from 0 by 2, 5, and 10 s; 5. Counting from x (where x > 0) by 2, 5, and 10 s; 6. Extending and applying counting skills.

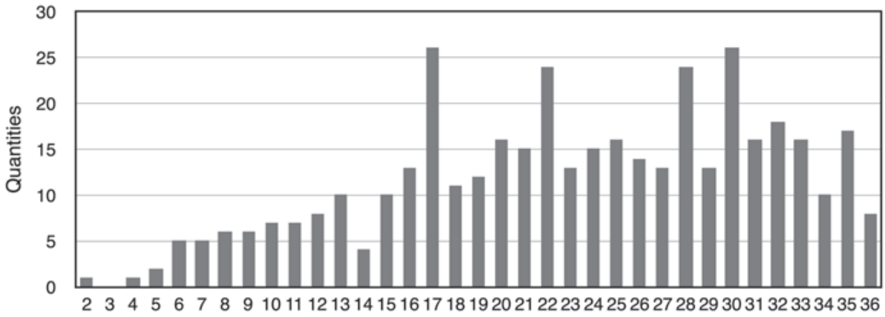

Fig. 5.2 DEMAT 1+ raw values at MP 3

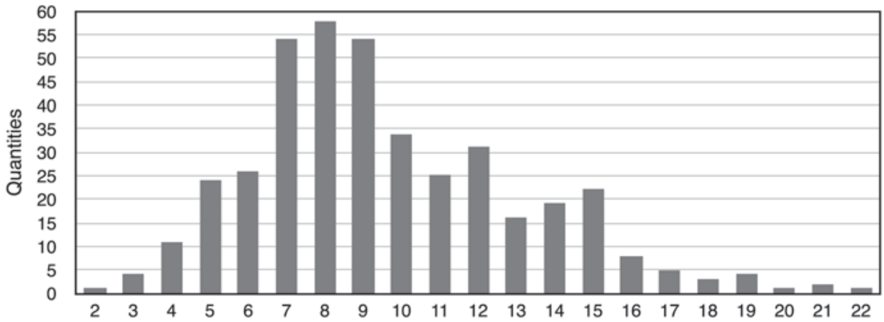

Fig. 5.3 EMBI score sums at MP 3.

was used to eliminate the children with low performance in only one of both tests. In this respect the standardised DEMAT 1+ values provided a pre-selection of the lowest 20% (DEMAT 1+ raw value <20), which was further validated with the children's performance in the EMBI.

For this validation the overall scores in the DEMAT 1+ (see Fig. 5.2) were analysed and compared with the overall scores in the EMBI (see Fig. 5.3). The analysis of the performances in the EMBI showed that the lowest 16% did not reach 7 points or more and there was a significant break ($p < 0.001$) between the groups scoring 6 and 7 points respectively, which was used as a further criterion to identify the low achievers at the end of Grade 1. As a result 49 children (12% of the complete sample) performed low in both the standardised test and the interview as well, while the majority of the children tested and interviewed (88%) demonstrated elaborate abilities and knowledge as described by Anderson et al. (2008, pp. 126–127). This group of 49 children provides the basis for all further analyses.

With respect to the overall sample children with migration background are significantly ($p < 0.001$) overrepresented in the group of low achievers (35 of 49 children, 71.4 %), while there is no major difference in the gender distribution (21 male, 28 female) to the overall sample.

5.5.2 Performance on the DEMAT 1+ Subtests and EMBI Interview Parts

The group of low achieving children showed significant ($p<0.001$) differences in their performance on the DEMAT 1+ and on the EMBI in comparison to the remaining group ($n=359$). With respect to the standardised test the low-achieving first graders ($n=49$) reached significantly lower scores ($p<0.001$) in all nine DEMAT 1+ subtests (see Table 5.2). Their results on all four interview parts of the EMBI (see Table 5.3 for) were also lower than for the remaining first graders; the median growth points for the low achievers were one to two growth points less in each of the four domains.

Apart from domain A (*counting*) the low achieving first-graders reach only the first growth point in each domain. The greatest difference between the remaining first graders and the group of low-achievers is shown in domain C (*strategies for addition and subtraction*), where the difference in medians is two growth points (see Table 5.3).

Table 5.2 DEMAT 1+ subscales at MP 3

Subtest	DEMAT 1+ Subscales at MP 3			
	Remaining children in the sample ($n=359$)		Low achieving first-graders ($n=49$)	
	Mean	SD	Mean	SD
Sets—numbers	2.715	0.581	2.163	0.799
Number-line activities	3.799	1.105	2.375	1.248
Addition	3.086	1.086	1.469	1.234
Subtraction	2.150	1.498	0.734	1.106
Finding the 2nd addend	2.891	1.288	1.163	1.328
Part-whole	2.217	1.629	0.489	0.844
Addition with more than one addend	2.459	1.375	0.918	0.975
Understanding of "<, >, ="	2.838	1.237	1.857	1.172
Word problems	2.476	1.592	1.163	1.027

Table 5.3 Median growth point EMBI at MP 3

Content domains	MP 3 EMBI growth point scores	
	Remaining first graders in the sample ($n=359$)	Low achieving first-graders ($n=49$)
	Median	Median
A. Counting	3	2
B. Place value	2	1
C. Strategies for addition and subtraction	3	1
D. Strategies for multiplication and division	2	1

5.5.3 Achievement Prior to School (MP1 and MP2)

The basis for the analysis of the data collected at MP 1 and MP 2 is the identification of low-achieving first graders at MP 3 ($n=49$). This group of children is compared to the remaining children in the sample ($n=359$).

In order to assess the children's performance on the EMBI-KiGa, the interview results were translated into number scores (0 to 1 point for each of the 11 items in order to balance the influence of each item on the total score, acknowledging the fact that the number of sub-items varies).

The analysis of the data from MP1 and MP2 showed that the group of low-achieving first graders already performed lower prior to school entry. Their total scores on the OTZ and their overall scores on the EMBI-KiGa (MP 1: Low achieving first-graders: Mean: 3.159, SD: 1.775—Remaining sample: Mean: 6.632, SD: 2.230; MP 2: Low achieving first-graders: Mean: 6.693, SD: 1.978—Remaining sample: Mean: 8.972, SD: 1.337) show significant ($p<0.001$) differences. While the overall scores at MP 2 are higher for both groups as expected, the significant difference between the groups remains at an average difference of about 2 points.

5.5.4 Analysis of the Performance with Respect to the Different Content-Specific Items in the OTZ and the EMBI-KiGa

The analysis of the low achieving first-grader's performance on all eight subtests of the OTZ (see Table 5.4) shows significant ($p<0.001$) differences for both MP 1 and MP 2. While the low achieving first-graders show moderate improvement on most subtests, they achieve major improvement in the subtests *comparing*, *number-line activities* and *one-to-one correspondence*.

In addition, Table 5.5 shows the mean scores on each of the 11 content specific items for each group at MP 1 and MP 2. For MP 1 *numbers before and after* appears to be the most difficult item overall (mean=253), followed by *ordering numbers 0–9* (mean=470), *subitising* (mean=502), *matching numerals to dots*

Table 5.4 OTZ mean scores at MP 1 and MP 2

Subtest	MP 1				MP 2			
	Children not at Risk ($n=359$)		Children at Risk ($n=49$)		Children not at Risk ($n=359$)		Low-achieving first-graders MP 3 ($n=49$)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Comparing and counting small sets	4.18	0.962	3.12	1.235	4.70	0.598	4.43	0.890
Number-line activities	3.75	1.067	2.84	1.106	4.47	0.772	4.00	1.000
One-to-one-correspondence	3.03	1.243	1.80	1.307	3.99	0.860	3.29	0.913
Ordering/seriation	2.14	1.562	1.08	1.057	3.51	1.355	1.92	1.397
Using number words	3.12	1.445	2.22	1.031	3.59	1.195	2.33	1.281
Counting all/Counting on	3.10	1.278	2.09	1.033	3.27	1.139	2.22	1.177
Counting (un-) structured sets	2.49	1.255	1.32	1.097	2.61	1.349	1.61	1.133
Word problems	3.47	1.355	2.31	1.979	3.52	1.202	2.08	1.115
Total scores	21.04	6.889	12.96	5.156	29.67	5.473	21.92	5.235

Table 5.5 EMBI-KiGa Mean scores MP 1 and MP 2

Content domains	MP 1				MP 2			
	Children not at Risk ($n=359$)		Children at Risk ($n=49$)		Children not at Risk ($n=359$)	Children at Risk ($n=49$)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Comparing and counting small sets	0.688	0.338	0.377	0.298	0.812	0.267	0.663	0.344
Language of location	0.785	0.411	0.387	0.492	0.949	0.218	0.775	0.421
Pattern	0.540	0.349	0.295	0.304	0.825	0.255	0.602	0.288
Ordinal number	0.612	0.423	0.122	0.298	0.901	0.243	0.653	0.397
Subitising	0.522	0.181	0.357	0.250	0.626	0.217	0.520	0.175
Matching numerals to dots	0.547	0.322	0.193	0.246	0.779	0.254	0.622	0.260
Ordering numbers	0.523	0.500	0.063	0.247	0.857	0.349	0.551	0.502
Part-whole	0.562	0.300	0.255	0.252	0.686	0.245	0.489	0.161
Numbers before/after	0.280	0.328	0.051	0.152	0.635	0.345	0.326	0.298
One-to-one correspondence	0.919	0.272	0.836	0.373	0.958	0.200	0.898	0.305
Ordering by length	0.614	0.453	0.224	0.368	0.938	0.225	0.591	0.475

(mean = 504), *pattern* (mean = 511), *part-whole* (mean = 525), *ordinal number* (mean = 553), *ordering by length* (mean = 567), while *comparing and counting small sets* (mean = 650), *language of location* (mean = 737) and *one-to-one correspondence* (mean = 909) clearly appear to be the least difficult items.

The group of low achieving first-graders 1 year prior to school severely struggles with *numbers before and after* (mean = 051) *ordering numbers 0–9* (mean = 063), and *ordinal number* (mean = 122). Overall this group performs significantly worse ($p < 0.001$) in all content specific items apart from *one-to-one correspondence* ($p > 0.1$) which is also the case for MP 2 (see Table 5.5).

While the group of low achieving first graders overall showed improvements in all categories of the EMBI-KiGa from MP 1 to MP 2, they still score significantly ($p < 0.001$) lower than the remaining sample (apart from *one-to-one correspondence*). There is still a major difference on their performance in the areas *ordinal number* (0.653), *ordering numbers* (0.551), *part-whole* (0.489), *numbers before/after* (0.326) and *ordering by length* (0.591).

5.6 Discussion and Implications

The analyses of the data collected in MP 1 to MP 3 suggests that low-achieving first-graders already demonstrate a significantly lower understanding of sets and numbers and significantly less elaborate counting skills than their peers prior to school at both measuring points—1 year before school and immediately before school entry. These results conform to studies by Aunola et al. (2004). Furthermore, children with a migration background are clearly overrepresented among the low-achieving first-graders (Peter-Koop and Grüßing 2014, p. 315). With respect to their performance on the EMBI and the DEMAT 1+ the low-achieving children demonstrate significantly lower achievement in all four content domains (EMBI) and all subtests (DEMAT 1+). They particularly struggle with respect to the DEMAT 1+ items on *subtraction*, *part-whole relationships*, *addition with more than one addend* and *finding the second addend*. However, the subtests on part-whole relationships, subtraction, addition with more than one addend and word problems proved to be the most difficult items for their higher achieving peers. With respect to subtraction a longitudinal study by Cooper et al. (1996) indicated that second graders were overall more successful on addition tasks of varying difficulty than on respective subtraction tasks.

In contrast to the standardised DEMAT 1+ that focuses on correct results, the EMBI seeks to identify strategies that children apply when given mathematical tasks and problems. With this respect the identified group of low-achieving first-graders demonstrates less elaborate strategies for addition and subtraction. This can be seen in relation to their understanding of number and their number skills prior to school. In order to solve problems such as 8 + 6 with strategies other than counting, an understanding of part-whole schema (Resnick 1989) is necessary to be able to add up to 10 and then on (e.g., 8 + 2 + 4). While they still struggle with part-whole

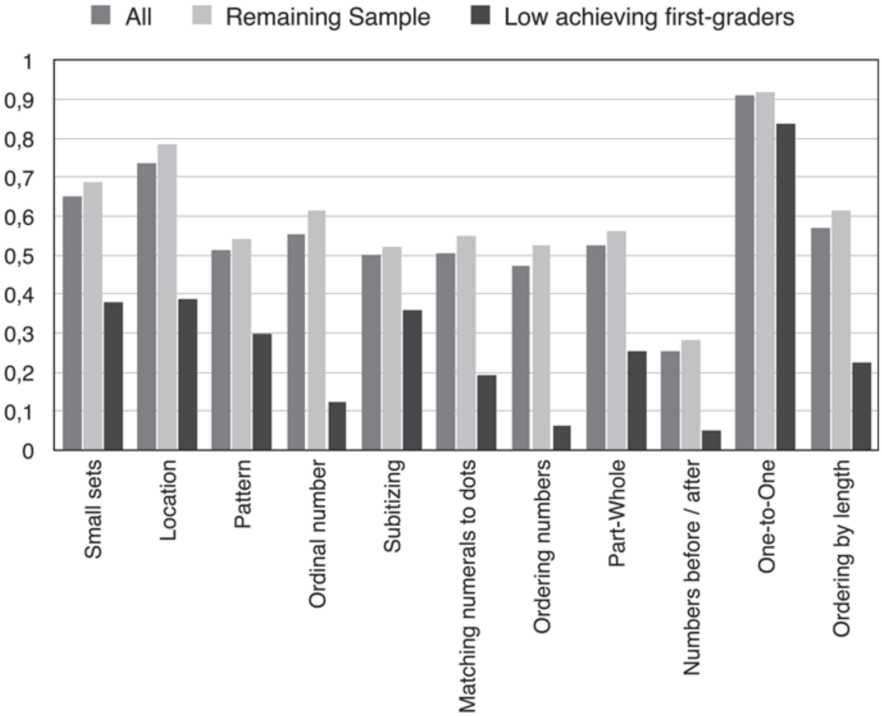

Fig. 5.4 EMBI-KiGa subcategory mean scores MP 1

relationships in Grade 1 (see Table 5.2), they already demonstrated less insight into this concept than their peers prior to school at both MP 1 and MP 2 (see Table 5.5). Furthermore, the low-achieving first graders demonstrate less insight in counting and place value (see Table 5.3). This means that their higher achieving peers have significantly more elaborate knowledge and skills with respect to higher numbers. How far this can be compensated for at the end of Grade 2 so far remains unclear.

When considering the performance of the children who are identified as low-achievers in mathematics at the end of Grade 1, it is also interesting to note that they obviously experience special difficulties with respect to items that require more elaborate language skills, i.e. language of location, numbers before/after and ordinal numbers (see Figs. 5.4 and 5.5). This might explain the overrepresentation of children with a migration background.

However, since the assessment of German language competencies has not been included in the study design, this possible relationship needs to be further investigated.

Moreover, the low-achieving first-graders prior to school also demonstrated significantly less knowledge and understanding of number symbols, which suggests that their command of the German language might only be one factor among others that would explain why they tend to struggle with the development of number skills and counting much more than their peers.

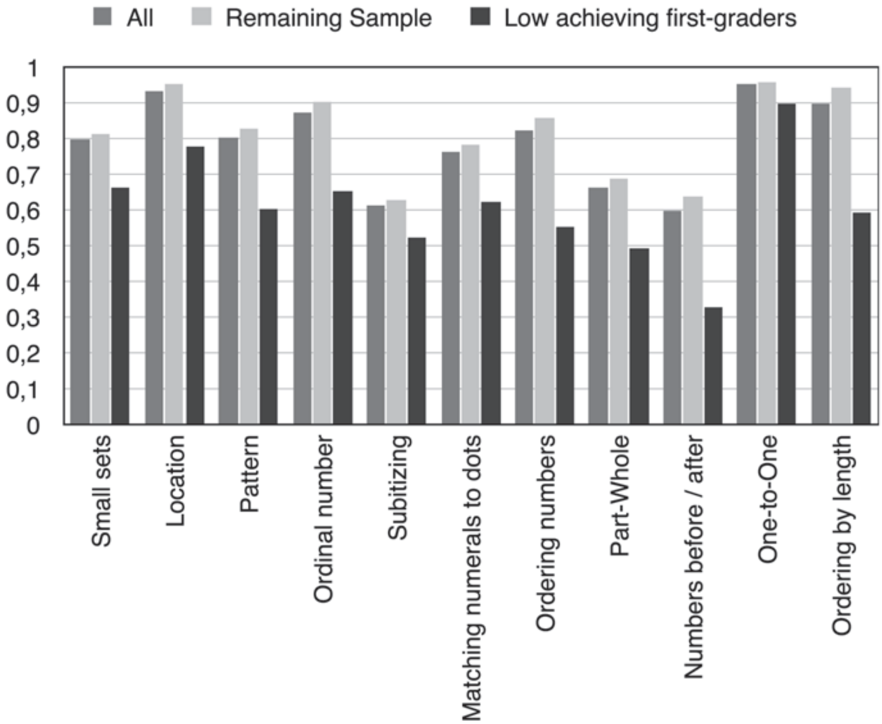

Fig. 5.5 EMBI-KiGa subcategory mean scores MP 2

However, as Table 5.5 as well as the comparison of Figs. 5.4 and 5.5 suggest, this group of children does improve from MP 1 to MP 2. Immediately before school entry they show about the same average scores on the EMBI-Kiga (mean = 6.693) as their peers did 1 year before school entry (mean = 6.632). This complies with findings of a longitudinal study conducted by Aunola et al. (2004). They describe the cumulative effects of children having little number-related knowledge and skills prior to school, i.e. preschoolers who demonstrated low competences in dealing with numbers and sets clearly showed slower development of their mathematical competencies in primary school with an increasing gap with respect to their peers who started school with higher number skills and knowledge.

In summary the study in progress reported in this chapter confirms previous findings that understanding and skills with respect to number and counting are important precursors for later school success. The children who were identified as low-achievers in mathematics at the end of Grade 1 demonstrated significantly lower knowledge and skills than their peers prior to school. However, the results presented and discussed here provide only first insights into the development of number skills and counting ability.

Furthermore, the data suggest that the EMBI-KiGa is a suitable screening instrument for the identification of children potentially at risk learning mathematics, especially because of its focus on strategies and skills as well as the fact that it is conducted as a one-to-one interview that allows for children to use concrete objects/manipulatives to demonstrate and articulate their mathematical understanding in addition or even as a replacement for verbal explanations.

In addition, more detailed analyses of the individual development of the children will help to better understand and describe the factors that explain the differences in achievement in the transition from kindergarten to school. Hence, further in-depth analyses will include qualitative approaches in the form of individual case studies. With respect to the model of early mathematical development by Krajewski and Schneider (see Fig. 5.1) first broad analyses suggest that the children who later struggle in Grade 1 mathematics, prior to school entry only demonstrate competencies that can be assigned to the first level and partly to the second level, while their better achieving peers show competencies that comply with level two and three. Further in-depth analyses of the development, which has been recorded in the study, will provide more detailed insight into the transitions between the levels and their influence on school mathematics learning.

Ultimately, a more extensive competence model of children's developing mathematical skills is required that not only focuses on numerical skills and understanding but includes children's language abilities and comprehension as well as their spatial and structural abilities.

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