SUPPORTING CHILDREN POTENTIALLY AT RISK IN LEARNING MATHEMATICS – FINDINGS OF AN EARLY INTERVENTION STUDY

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Recent psychological studies as well as research findings in mathematics education highlight the significance of number skills for the child's performance in mathematics at the end of primary school. In this context, the three year longitudinal study (2005-2008) involving years K – 2 that provided the background of this paper seeks to investigate the influence of intervention based on number skills prior to school on children's later achievement in primary school mathematics. Following an overview of the theoretical background and the design of the study, quantitative findings from the first year of the study regarding the mathematical achievements of children potentially at risk learning school mathematics one year and immediately prior to them starting school will be presented and discussed.

BACKGROUND AND FOCUS OF THE PAPER

Children start to develop mathematical knowledge and abilities a long time before they start formal education (e.g. see Anderson, Anderson, & Thauberger 2008; Ginsburg, Inoue, & Seo, 1999). In their play and their everyday life experiences at home and in child care centres they develop a base of skills, concepts and understandings about numbers and mathematics (Baroody & Wilkins, 1999). Anderson et al. (2008) recently reviewing international studies on preschool children's development and knowledge conclude that research

> (…) points to young children's strong capacity to deal with number knowledge prior to school, thus diminishing the value of the conventional practice that pre-number activities are more appropriate for this age group upon school entry. (p. 102)

However, the range of mathematical competencies which 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 knowledge about numbers (e.g. see Clarke, Clarke, Grüßing, Peter-Koop 2008). Furthermore, recent clinical psychological studies suggest that children most likely to develop learning difficulties in mathematics can already be identified one year prior to school entry by assessing their number concept development (Krajewski 2005; Aunola, Leskinen, Lerkkanen, & Nurmi, 2004). Findings from these studies also indicate that these children benefit from an early intervention prior to school helping them to develop a base of knowledge and skills for successful school-based mathematics learning. This seems to be of crucial importance as findings from the

SCHOLASTIK project (Weinert & Helmke, 1997) suggest that students who are low achieving in mathematics at the beginning of primary school in general tend to stay in this position. In most cases, a recovery does not occur. In addition, Stern (1997) emphasises that subject-specific previous knowledge is more important with respect to success at school than general cognitive factors such as intelligence. Thus, the study reported in this paper aims to investigate how children potentially at risk in learning school mathematics can be identified one year prior to them starting school and compares the effects of early intervention on one-on-one basis carried out by student teachers with that of small group interventions

DEVELOPMENT OF NUMBER CONCEPT

While pre-number activities based on Piaget's *logical foundations model* are frequently still current practice in the first year of school mathematics (Anderson et al. 2008), research findings as well as curriculum documents increasingly stress the importance of students' early engagement with sets, numbers and counting activities for their number concept development. Clements (1984) classified alternative models for number concept development that deliberately include early counting skills (Resnick, 1983) as *skills integrations models*.

Piaget (1952) assumed that the development of number concept is based on logical operations based on pre-number activities such as classification, seriation and number conservation and 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, subitzing and comparing. Studies by Fuson, Secada, & Hall (1983) and Sophian (1995) for example demonstrate that children performing on conservation tasks who compare sets by counting or using a visual correspondence are highly successful. Clements (1984) investigated the effects of two training sequences on the development of logical operations and number. Two groups of four-year-olds were trained for eight weeks on either logical foundations focussing on classification and seriation or number skills based on counting. A third group with no training input served as a control group. Instruments measuring logical operations and number abilities were designed as pre- and post-test measures. It is not surprising that both experimental groups significantly outperformed the control group in both tests, however, the children that were trained on number skills significantly outperformed the logical foundations group on the number test while there was no significant differences between these two groups on the logical operations test. Clements' results comply with and extend previous research that had indicated that number skills such as counting and subitizing affect the development of number conservation (Fuson, Secada, & Hall, 1983; Acredolo, 1982). Hence, he concludes:

> (…) the counting act may provide the structure and/or representational tool with which to construct logical operations including classification and seriation, as well as number conservation. … Not only may explicit readiness training in logical operations be unnecessary, but well structured training in counting may facilitate the growth of these abilities as well as underlie the learning of other mature number concepts. (Clements, 1984, 774-775)

An early training based on number abilities such as counting, comparing and subitizing may be especially important for children who are likely to develop mathematical learning difficulties. The longitudinal intervention study reported in this paper investigates the identification and subsequent enhancement of preschool children potentially at risk learning school mathematics prior to their first year at school.

METHODOLOGY

Based on current research findings reported in the previous section, the longitudinal study (2005 – 2008) that provides the background for this paper seeks

- to investigate young children‘s mathematical understanding in the transition from Kindergarten to primary school,
- to evaluate appropriate assessment instruments, and
- to explore how children potentially at risk learning school mathematics can be supported effectively in terms of their number concept development in early childhood education.

This paper focuses on the third aspect – exploring the effectiveness of early intervention based on the following two underlying research questions:

1. What are the effects of an eight months intervention program aimed at the development of number abilities for kindergarten children (five-year-olds) identified to be potentially at risk learning school mathematics upon school entry?
2. In how far has the early intervention a lasting effect with respect to their achievement in mathematics at the end of grade 1 and grade 2?

In this paper however, due to space restrictions only the first of the two research questions will be addressed by comparing the performance of the children potentially at risk learning mathematics from two groups before and after an eight months intervention prior to school entry.

Overall, 1020 five-year-old preschoolers from 35 kindergartens (17 in urban, 18 in rather rural regions) in the northwest of Germany took part in the first year of the study (September 2005 – August 2006). With the permission of their parents these children performed on three different tests/interviews conducted at three different days within a fortnight by preservice mathematics teachers from Oldenburg University who had been especially trained for their participation in the study:

- the German version of the *Utrecht Early Numeracy Test* (OTZ; van Luit, van de Rijt, & Hasemann, 2001) – a standardized test aiming to measure children‘s development of number concept conducted in small groups involving logical operations based tasks as well as counting related items,
- the *First Year at School Mathematics Interview* (FYSMI) [1] developed in the context of the Australian *Early Numeracy Research Project* (Clarke, Clarke, & Cheeseman, 2006) – a task-based one-on-one interview aiming at five-year-olds which allows children to articulate their developing mathematical understanding through the use of specific materials provided for each task,
- the *Culture Fair Test* (CFT1) – an intelligence test for preschoolers to be conducted in groups between four and eight children (Cattell, Weiß & Osterland, 1997) in order to be able to control this variable with respect to the children identified at potentially at risk learning mathematics.

A total of 947 children performed on all three tests. Their data provided the basis of the quantitative analysis based on the use of SPSS. While the majority of the children interviewed demonstrated elaborate abilities and knowledge as described by Anderson et al. (2008), 73 children (about 8 %) in the sample severely struggled with certain areas relevant to the development of number concept such as seriation, part-part-whole-relationships, ordering numbers and counting small collections. They were identified as ‘children at risk’ with respect to their later school mathematics learning on the basis of their performance at the OTZ and the FYSMI. 26 of these 73 children (35.6 %) came from non-German speaking background families. However, only 13.6 % of the children in the complete sample (n=947) had a migrant background. Hence, these children from migrant families were over-represented in the groups of children potentially at risk.

The intervention program for the children identified to be potentially at risk learning school mathematics was conducted in two groups: Children in group 1 had weekly visits from a pre-service teacher who had been prepared for this intervention as part of a university methods course. The pre-service primary teachers were introduced to the children as `number fairies` who wanted to show them games and activities that they could later share with their peers. This was done to ensure that the children did not feel pressure and experience themselves as slow learners at a very early point in their education. The intervention program for the group 2 children in contrast was conducted by the kindergarten teachers within their groups. While the intervention in group 1 was done 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 challenging the children identified to be at risk in these areas. The kindergarten teachers completed a diary in which they described these situations, noted how often they arose and what they did with the children in the whole group (or a small subgroup as in a game situation) and with the children at risk in particular. Like in group

1 the children of group 2 were not aware of the fact that they took part in an intervention. However, the parents of all children that took part in the intervention had been informed and 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 in the form of an intervention as parents would not have agreed for their children to be part of this group.

In both groups the intervention was conducted over eight months, involving about 45 min a week and based on individual learning plans developed by the pre-service and kindergarten teachers. During the intervention the pre-service as well as the kindergarten teachers were supported by the researchers to the same degree to ensure comparability of the two groups. The activities were based on number work and counting activities following the skills integration model described above.

PRESENTATION AND DISCUSSION OF RESULTS

While it was to be expected that the performance of most children would increase from pre- to post-test due to age related advancement with respect to their cognitive abilities, the results of the study demonstrate that the total group of the children identified to be at risk in learning mathematics showed the highest increase. Figure 1 shows the means of the pre- and post-tests conducted in September/October 2005 and June/July 2006 comparing the complete sample with the children at risk. The analysis was based on the number of children that had completed all three tests in 2005 as well as the OTZ and FYSMI in 2006. Hence, the number in the complete sample decreased to n = 715 with 60 children (8.4 %) potentially at risk.

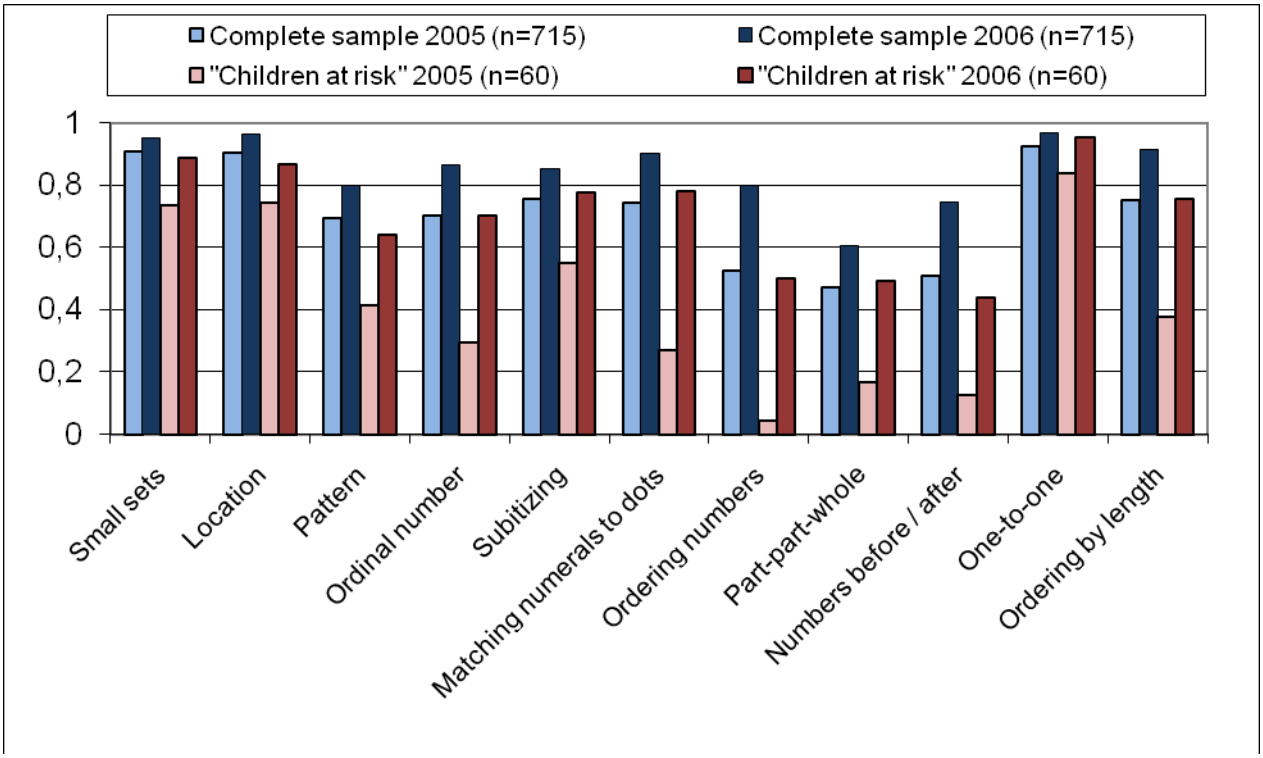

Figure1: Means of the pre- and post-test of the FYSMI

The data clearly shows that the children potentially at risk have in particular increased their competencies in those areas that were aimed at during the intervention, i.e. knowledge about numbers and sets as well as counting abilities, and performed significantly better in the post-test in the tasks related to *ordinal numbers*, *matching numerals to dots*, *ordering numbers*, *numbers before/after* and *part-part-whole relationships* [2]. However, it is important to note that due to the fact that for ethical reasons a control group was unavailable, a distinct effect of the intervention omitting other potential factors cannot be substantiated by this particular research design. Furthermore, ceiling effects hamper the comparison of the increase in mathematical competencies between the whole sample and the group of children identified to be potentially at risk in learning school mathematics. Despite this, the children potentially at risk undoubtedly demonstrated increased number knowledge and skills – domains which are seen as key predictors for later achievement in school mathematics (Krajewski 2005, Aunola et al. 2004).

Data from this study also suggests that children from non-German speaking background families show lower competencies in number concept development one year prior to school entry than their German peers. A comparison of the FYSMI pre-test data of the children with German as their first language and the children with a migration background based on a total of 947 children who completed the interview (see Fig. 2), shows a significant difference in achievement ($p < 0.001$) in the areas language of location, *subitizing*, *matching numerals to dots*, *ordering numbers* and *numbers before and after*.

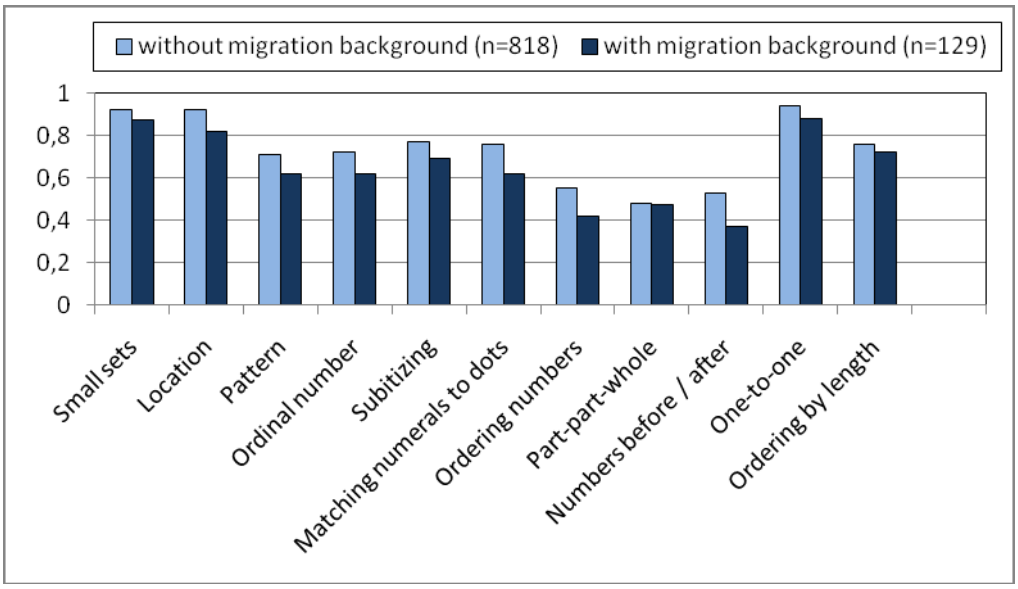

Figure 2: Mean scores of children with a migration background and German speaking background children in the FYSMI pre-test

Complying with these results, children with a migration background demonstrated significantly lower counting abilities with respect to the number related items in the OTZ. A detailed investigation of these results indicates that language related factors

play an important role. In the sub-group of the children from Turkish families [3] it was found that most of these children identified as potentially at risk in learning school mathematics, showed better performances in counting and number activities when they were encouraged to answer in Turkish (Schmitman gen. Pothmann, 2008). Thus, the intervention obviously proved beneficial with respect to their mathematical performance in the German language. The 23 children with a migration background in the group of 60 children identified potentially at risk demonstrated a clear increase in achievement in the post-test. While the achievement of both groups significantly increased ($p < 0.001$) within the test interval, these children on average 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 the 37 children from German families. However, the difference in achievement between these two groups is not significant ($p = 0{,}164$). In comparison, the growth in achievement in the group of children with migration background but without a potential risk factor in terms of their school mathematics learning is 1.3 points, while the mean score in this group of German children is 1.1. Again, the difference between those two groups ($p = 0{,}629$) in not significant (ibid, 161). Immediately before school entry the mathematical competencies of children with and without migration background obviously have converged – in some areas, i.e. *matching numerals to dots*, *ordering numb*ers and *part-part-whole*, they even show slightly (however, not significantly) better results (ibid, 121).

And also another finding with respect to early intervention for preschoolers identified to be potentially at risk in learning school mathematics is encouraging. With respect to the substantial increase in achievement demonstrated by the 60 children with a risk factor in the FYSMI post-test, no significant difference between the group of 13 children who worked once a week with pre-service teachers introduced as number fairies (group 1) and the remaining 37 children who received remedial action within their groups by their kindergarten teachers (group 2) was found (Fig. 3).

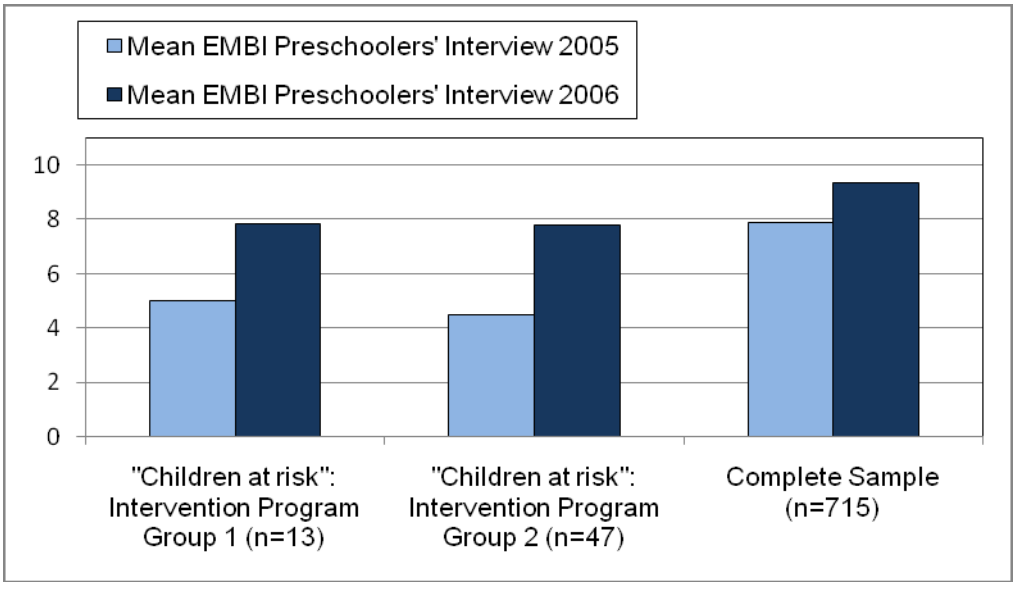

Figure 3: Mean score of the FYSMI comparing the two intervention groups

This suggests that an intervention in the everyday practice by the kindergarten teacher who had received professional development in this area is as effective as a weekly one-on-one intervention by a visiting and hence more cost-intensive outside specialist. In addition, Figure 3 shows a clear increase in achievement in both groups of an average 2.5 points in group 1 and even 3.2 points in group 2 which is clearly higher than the increase in the complete sample (see above).

IMPLICATIONS

The findings of the study suggests that preschoolers who had been identified as potentially at risk in learning school mathematics one year prior to school entry could benefit significantly from an eight months intervention program based on the enhancement of number knowledge and counting abilities. Data from the pre- and post-tests clearly indicate increased knowledge, skills and understanding of numbers and sets, i.e. particularly those areas of number concept development regarded as predictors for later achievement in school mathematics (Krajewski, 2005, Aunola et al., 2004). Further analyses suggest that for more than 50 % of these children this increase in their mathematical achievement prior to school entry proves to be of lasting effect at the end of grade 1 (Grüßing & Peter-Koop, 2008). In how far this will hold true at the end of grade 2 is currently under investigation.

Furthermore, there were no significant differences in achievement found in the post-test between the groups of children that had experienced a one-on-one intervention by the preservice mathematics teachers who had been particularly trained for this task, and the children that had worked with their kindergarten teachers within their home groups. While clinical studies had already shown positive effects of early intervention (e.g. Krajewski 2005), this study suggests that there is not necessarily a need to bring external specialists into the kindergarten to work with individual children [4]. A comprehensive screening and respective enhancement of preschoolers potentially at risk by their kindergarten teachers is possible – given that the kindergarten teachers are prepared for this task during their initial and/or inservice training.

In addition, the findings show that children with a migration background are not only over-represented in the group of preschoolers with a risk factor with respect to school mathematics, they also demonstrated the highest increase in mathematical achievement in the test interval. Hence, it appears to be important not only to focus on screenings that determine (German) language development prior to school as it is currently done in all German states, but also to investigate early mathematical abilities in order to identify children who need extra support in their number concept development. Since the PISA study has emphasized that the group of migrant children is overrepresented among the low achieving students at the age of 15 (Deutsches PISA-Konsortium, 2001) and findings from the SCHOLASTIK project (Weinert & Helmke, 1997) indicate that low achievers in mathematics at the beginning of primary school in general stay in this position, this seems of crucial importance. While the German version of the *Utrecht Early Numeracy Test* (van Luit et al., 2001) – the OTZ – showed clear ceiling effects and also proved to be very

difficult for non German speaking background children due to its demands on German language comprehension, his study suggests that the FYSMI (Clarke et al., 2006) is a suitable instrument for the collection of information on preschoolers' number concept development and the respective identification of children potentially at risk in learning school mathematics. This instrument allows children to articulate their developing mathematical understanding through the use of simple materials provided for each task in a short one-on-one interview that takes about 10 to 15 minutes for each child. Bruner (1969) has already highlighted the importance of material based activities for young children who for various reasons cannot yet verbally articulate their developing and sometimes already yet quite elaborate (mathematical) understanding.

NOTES

1. The FYSMI is designed to be conducted in the first year of school, which in Australia is the preparatory grade preceding grade 1. This preparatory year is compulsory for all five-year-old children. In Germany in contrast, formal schooling starts with grade 1 when children are six years old. While a majority of German five-year-olds attend kindergarten, this is not compulsory and involves fees to be paid by the parents.

2. The analysis of the data from the standardised OTZ showed clear ceiling effects. Over 40 % of the children reached level A which supposedly represents the top 25 % of the children in this age group. However, in level E representing the bottom 10 % of the scale, the test differentiated sufficiently with respect to the sample.

3. The majority of the children with a migrant background in the sample was from Turkish parents, followed by families from Russia, Kazakhstan, Lebanon and Iraq.

4. However, it is acknowledged that there might be cases in which a specialist based one-on-one training in addition to the help provided by the kindergarten teacher is expedient.

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