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Community of Practice for Social Systems Strengthening to Improve Child Well-being Outcomes

Progress in the First Grade: Assessment of Children in a Social Development Project

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Abstract

To find out how Grade 1 children in an interdisciplinary development project progress during their first year of school, two standardized instruments and one custom-designed picture vocabulary tool wer used to assess their competence in three components of the first grade curriculum, namely reading, numeracy and vocabulary. In the sample, 159 children in five schools in the area of greater Johannesburg were assessed individually at the beginning during their first school year . The children's families all receive a social development grant from the South African government. The differences between the groups of children are their specific school and its first-grade teachers, the language in which they are taught, as well as the everyday life in their communities. The results can be used in the project's overall description of the development and the wellbeing of the children.

Introduction

The assessment of children's early progress in the development of foundational reading skills and number concepts plus concomitant vocabulary knowledge serves important diagnostic purposes regarding individuals; it also gives an indication of the enactment of the curriculum in a particular school or in a sample of a specific learner population. A baseline of number concept development, using a standardized interview-based test (Henning et al., 2019) along with a test of early literacy, focusing on the phonology and visual recognition of initial reading (RTI International, 2016) and the Meerkat Maths Language Test (MMLT) (Bezuidenhout, 2019) give teachers a glimpse of the individual differences in their class and alert them to possible learning support for individuals (Aunio et al., 2021; Desoete, 2015; Henning & Simelane, in press). If such a baseline serves as the first timepoint of the measurement of competence, a second assessment at a later stage can reflect progress in some detail. In the project, the test results can add to the variety of measures used to capture the everyday reality and wellbeing of participants, adding to an amalgamated description of the children of families that receive social development grants from the South African government.

This working paper discusses the three instruments used in the study with the emphasis on the theoretical underpinnings and the origins of the tests. The instrument for the assessment of early number concept development, published in South Africa as the MARKO-D SA test, provides succinct results per individual. The Early Grades Reading Assessment (EGRA) assesses children's first steps into literacy. The Meerkat Maths Language Test (MMLT) was selected because it assesses vocabulary knowledge required for early mathematics learning (Figure 1).

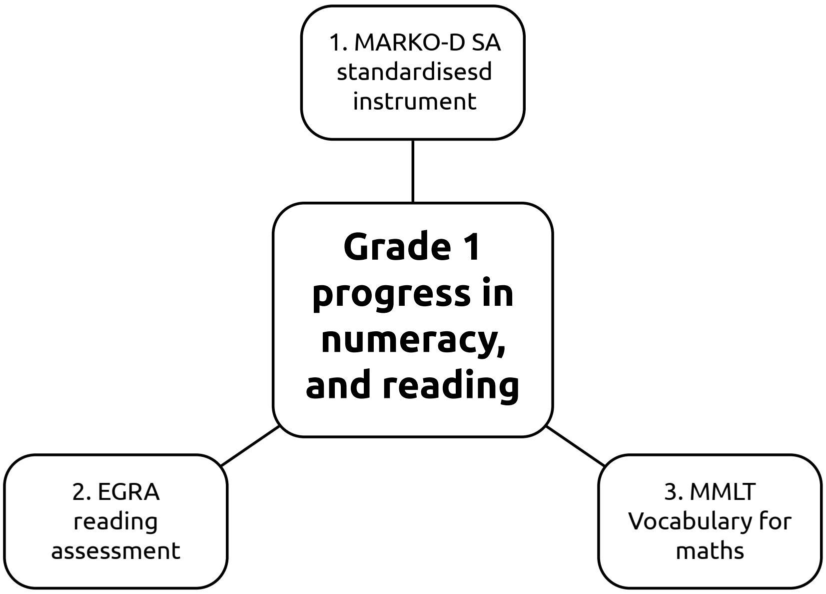

Figure 1: The tests to measure progress

We introduce the three tests in the order that they are usually administered per child.

Test One: The MARKO-D SA Test for Early Number Concept Development

There is ample evidence from the research literature about the predictive power of early number concept development for learning mathematics throughout children's school years (Aunio, Korhonen, Ragpot, Törmänen & Henning, 2021; Bezuidenhout, 2020, Desoete, 2015; Wijns et al., 2020). Many authors, from a range of research domains, have argued that children become increasingly 'number aware', based on the innate number knowledge of humans. The first one of these is a specific type of *number sense*, which makes it possible for infants to distinguish between up to three objects. Known as the object tracking system (OTS) (Carey, 2009), this ability was first demonstrated by Karen Wynn (Wynn, 1990, 1992) in experiments with young infants. It has been verified by studies across the fields of developmental cognitive psychology (Carey, 2009; Feigenson, Spelke & Dehaene, 2004; Sarnecka & Carey, 2012; Sarnecka & Wright, 2013; Spelke, 2017) and cognitive neuroscience (Dehaene, 2011; Spelke, 2000), as well as mathematics education (Clements & Sarama, 2009; Gelman & Gallistel. 1987).

The second innate number knowledge of human beings (and some animal species) is the ability to distinguish between the magnitude of two quantities, which makes it possible to distinguish the size of one number, compared to another. This innate number knowledge is known as the approximate number sense (ANS) (Carey, 2009; Dehaene, 2011). Some authors argue that the ANS is the basis for the further development of number concepts. They argue that these concepts develop further only through some type of deliberate instruction: Neuroscientist Stanislas Dehaene and his team have shown that, in different parts of the world, understanding (and naming) of number occurs as a result of instruction and also as apprenticeship, and in some instances works on other number bases or frameworks and not the base of 10, which is what the majority of children encounter when they start school (Pica, Lemer, Izard & Dehaene, 2004). Such 'instruction' may happen informally in the home and community through medium of language and demonstration but, ultimately number concept development relies on systematic instruction in settings where children learn to calculate and to reason about numerosity and do so by using mathematical symbols. The Arabic number symbol system is used in formal education across the globe, with most mathematics education programmes based on theories of number concept development, such as the one that undergirds the testing instrument that is used in the current project (Dehaene & Cohen, 2011; Clements & Sarama, 2009, 2013; Fritz, Balzer, Ehlert, 2013).

Henning and Ragpot (2015) offer a review of some of the literature about children's entry into the world of symbolic learning, when they become users of not only language symbols, but also the symbols of numeracy and of other components of mathematics and science. The authors comment:

> One of the vexing questions of cognitive developmental research is about the onset of symbolic knowledge, especially how pre-school children's concepts of number develop once they begin to use language - and other symbols.(Henning & Ragpot, 2015, p. 3)

On the view of innate number knowledge and language development that precedes number learning at school, various research teams have developed instruments to assess early numeracy development. In our work with such a team from the University of Duisburg-Essen and Potsdam University, we have adopted the standardised test that was designed by the team in the German language and translated and validated it in four South African languages originally, with two being added currently. The South African version of this test, with the acronym, MARKO-D SA[1], was published in 2019. The test is suitable for children in the 4 - 8 age-group. It consists of 48 items and the difficulty ranges across five levels of competence, as obtained from the Rasch item response theory (IRT) model (Henning et al., 2019)

The test captures five levels of performance, based on athemodel of number concept development (Fritz, Ehlert & Balzer, 2013). The model is described as follows in the MARKO-D SA Manual (Henning et al., 2019, Section 3.2).

A Cognitive Model of Number Concept Development

The key assumption of all competence level models is that the acquisition of a certain competency can be described hierarchically, with knowledge observable at levels that build on one another. Thus, competencies in a certain learning domain can be understood as a continuum on which different levels of proficiency can be distinguished. With regard to early numeracy learning, it means that basic arithmetical concepts (and also spatial reasoning and other mathematical concepts) are formed successively, with increasing conceptual sophistication as learning progresses. The empirically cross-sectional and longitudinally validated "Model of Development for Arithmetic Concepts" (Fritz, Ehlert & Balzer, 2013) describes the successive acquisition of arithmetic competencies and concomitant conceptual knowledge of children who are four to eight years old.

The five individual levels of concept development do not refer to encapsulated, single (modular) entities, but to overlapping development in a sequence. Rittle-Johnson, Siegler and Alibali (2001) refer to this notion as "overlapping

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[1] The acronym refers to 'mathematical and arithmetical competence'.

waves" of cognitive development. In the MARKO-D SA manual (Henning et al, 2019) the developmental levels feature in tasks in the number range up to 20.

Level I: Counting

Children's first experiences of natural numbers are coupled with their development of language around the age of two. They learn number words and soon they also learn the sequence of the words in a number word 'line'. At first, number words are non-semantic and remain a "list of meaningless lexical items" (Carey, 2009, p. 308), which is sometimes recited in a random sequence. Gradually, knowledge of the number word line stabilises, but children are still not able to utilise number words for authentic counting actions.

At this stage, young children are not able to select only a single object, even if they can recite the number word line up to ten. Gradually they learn the meaning of these words, or *numerals*: one – two – three and so forth. They are now able to enumerate up to four objects, by assigning each object to a number word, and by relying on the cognitive strategy of one-to-one correspondence. The comprehension of words for bigger numbers requires a stage of development - a process, which, according to Le Corre and Carey (2007), also happens successively and lasts minimally up to half a year for a new number concept, until the point at which a number word, such as "ten" has been fully grasped as a word for a specific quantity. The enumeration of quantities happens on this level only by counting in a fixed succession.

Level II: Ordinal number line

A change in the representation of numbers takes place when numbers become associated with the order of successive quantities and how these are represented on what has become known as the 'mental number line'. Dehaene (2011) describes the mental number line as "a linear space extending continuously from small to larger numbers" (p. 264), on which "later in the list" is equated to "greater number" – but that is all.

The construction of a linear number line enables children to identify preceding and succeeding numbers. As the numerical quantity along the line becomes progressively larger/longer, the numbers that appear further on the line represent larger quantities. With the knowledge of the increasing value of the number word line, children begin to understand additive relations and are able to complete addition tasks. They count out the individual numbers one-by-one, with the underlying idea of 'moving forward' on the number line. Children with the conceptual knowledge of this level are only able to compute by means of counting. Unless they develop the concept of cardinality, their counting strategy will remain a dominant strategy.

Level III: Cardinality

When children grasp the notion of cardinality, they are ready to embark on a numerical development journey. In the 'counting out' procedure of, for example, seven objects, each object will be assigned a number word and the summation, captured by the final counting word, captures the whole of the set. Once it is understood that a number is a composite unit that consists of individual elements, it becomes clear that numbers can be decomposed (broken up) as well. A set of seven elements can be partitioned into two subsets in different ways, while the whole quantity of elements does not change.

The cardinality principle in number concept development is the key prerequisite for the acquisition of effective calculation strategies. The addition of 7 + 8 = 15 no longer requires counting, but can be done by decomposing the numbers adequately. For example, 8 can be decomposed in 3 and). The task can be completed in various ways: 7 + 8 = 15 ; 7 + 3 + 5 = 15.

Level IV: Part-Part-Whole relations (PPW)

With the development of cardinality as a concept , a child understands that each number is composed of various combinations of smaller numbers, so that each number can be decomposed systematically. The also learn that the meaning of a number does not change during decomposition, because it can be recomposed,

Fuson (1992, p. 95) considers the relation of subsets and totals as "numerical equivalence", since subsets combined are "equivalent to the sum" In this sense, the relation between the parts and the whole is determined. Parts and whole together form a triadic relationship. For instance, the triad, 7–3–4 can be considered as follows: 7 (the whole set) has two subsets, consisting of 3 and 4 elements. The subsets of 3 and 4 together are equivalent to the whole 7 (3 + 4 = 7). If two quantities are known, the third one can be deduced, no matter which part is missing. Due to this logic, tasks which require the last quantity, the starting quantity, and the exchange quantity can be completed.

Level V: Equidistant number line intervals

Based on their cardinal knowledge of different numbers/quantities, children begin to realise that successive numerals 'one', 'two', 'three', and 'four' refer to sets that are related by adding one (+1); by now they know that the value of 'one' never changes. This realisation is coupled with an understanding that the magnitude of the difference between two consecutive numbers is always the same – it is *one*. Hence, in the number line representation, the distance between two consecutive numbers is always an equal distance, namely always one. With this knowledge, children have a type of scale at their disposal, which enables them to determine differences between two sets exactly. This also means that the same number of counting steps, or distances of equal length on the number line, have the same *cardinality*. The child now understands that the distance between *zero and five* is equivalent to the distance between *five and ten*.

The concept of the structured number line is a prerequisite for the understanding of multiplicative relationships as well as the concept of numerical place value.

This description of the five conceptual levels proposes that each level is characterised by a specific concept, which, developmentally, builds onto the previous concepts and prerequisites.

Assessing Number Concept Development

The aim of the construction of the original MARKO-D in Germany was to locate a child's performance on one of the hierarchically sequenced levels by means of the test.

Two questions had to be addressed:

1) How can one be sure that the tasks truly operationalise the specific concept of each level?
2) How can one be sure that the test captures children's understanding of the five different number concepts reliably?

The research team created an item pool according to the theoretical principles of Levels I – V, with a maximum of 70 items. In several pilot studies they trialled the items to establish their empirical fidelity and then modified them where necessary. Using Item Response Theory, they set out to find if all the items formed a one-dimensional cumulative scale, if items on specific segments of the scale could be identified, and whether the sequence of these segments on the scale followed the sequence of levels in the model. Altogether they tested more than 3,000 children during the process of conducting several pilot studies. This led to the design of the MARKO-D test instrument (Ricken, Fritz & Balzer, 2013) with 55 items.

Based on the German MARKO-D, the test was translated for use in South Africa. We translated and adapted the test culturally for children in this country and piloted its use in selected schools in Gauteng. The aim was to ensure that the instrument continued to assess the same constructs as in its original language - in other words, that the translated items retained the conceptual content of the original test.

A first translation was done from German into English. Children from three different age groups formed part of this first pilot; the groups were from Grade R, Grade 1 and Grade 2 learners (n = 224). The English version of the test was then translated into three other South African languages, namely isiZulu, Afrikaans and Sesotho. In total the translations went through five iterations during pilot studies. In the end, we were able to prove the validity of the model in all four languages. We had to delete some items, which were too easy or too difficult in one of the languages.

The first set of pilot studies in all four languages, was then conducted. The English and Afrikaans pilot studies showed similar results: the order of the items in these two languages corresponded to the order of the items in the German test. In the other two languages we conducted a couple of back-and-forth translations with guidance of African language linguists and assistance from a team of teachers.

The final test contains 48 items. The items form a one-dimensional cumulative scale with five distinguishable segments, according to the levels of the theoretical model. In total, each segment (or level) includes items of the respective level. Thus, the validity of the model and the test can be considered as proven in all four languages, which means that the model and the test are culture and language independent.

Special mention should also be made of the use of characters in the story that forms the backdrop of the test. In the original German version, squirrels were inserted as characters. This was not suitable for South African children. Therefore, the characters were changed to meerkats and the drawings made accordingly (Figure 2). For the drawings, the idea was to keep the illustrations non-invasive and minimalistic in terms of olour and background so as not to overload working memory. FiF

Figure 2: Meerkat characters in the test booklet

Test Two: The Early Grades Reading Assessment (EGRA)

This instrument is used widely in different parts of the world and is recommended by the Department of Basic Education in South Africa as a diagnostic tool in different languages. The EGRA Toolkit (RTI International, 2016) shows the components of the test, with which children's initial (and pre-literacy) phonological and reading skills can be captured. Data from a recent randomly selected study of Grade 1 – 3 learners (n = 287) in an isiZulu school, Simelane (in progress) showed that competent reading of the majority of children was achieved only after two years. The assessment of the learners in the present project showed similar results[2], depending on the language in which the children learn to read. Unlike the often-cited PIRLS test (Roux, 2921; Spaull & Kotze, 2015), which is administered to older children, the EGRA test captures the foundational reading competence of children in the early grades, where there is still much contention about systematic reading instruction through phonics (Brink, Motolo & Henning, 2021; Snow, 2018) and the increasing importance of the science of reading. The components of the test (Table 1) show that knowing the sound system of a language, coupled with knowledge of the vocabulary and grammar of the language, intersect systematically with a phonics approach to reading instruction.

Table 1. Components of the EGRA test used in the XXXX project

Early reading skill tested	Description of task	Rationale for including task
Letter identification	The child is asked to identify letters by stating the letter name or sound. The child is scored on the number of letter names or sounds correctly identified in 60 seconds.	Letter recognition tests the foundation for reading and is a regular determinant of reading development.
Familiar word reading	The child reads simple, frequently used, monosyllabic or bisyllabic words. The child is scored on the number of words correctly read in 60 seconds.	Familiar word reading tests the child's ability to decode and recognize words presented in isolation, without the advantage of context.
Invented word reading	The child reads simple invented words, testing the ability to determine pronunciation based on known relationships between letters or letter combinations (graphemes) and the sounds they represent (phonemes). The child is scored on the number of invented words correctly decoded in 60 seconds.	Invented word reading further tests the ability to decode words and avoids the problem of children recognizing words by memorization.

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[2] The results of the test will be published in future papers and were briefly discussed in a webinar on 15 September 2021)

Early reading skill tested	Description of task	Rationale for including task
Oral reading fluency	The child is given 60 seconds to read words in connected text. The child is scored on ability to read connected text accurately (number of words read correctly) and at a sufficient rate (number of words read correctly in 60 seconds).	Oral reading fluency is a strong measure of overall reading proficiency since it jointly tests multiple skills, including translating letters into sounds and decoding words.
Reading comprehension	The test administrator asks the child reading comprehension questions for the text the child just read. The child is scored on the percentage of questions answered correctly.	Reading comprehension questions are an additional test of reading proficiency. Students must make connections between words and assign meaning to those words.

The framework for the assessment of initial reading that we utilise for the interpretation of the test results is the recent amalgam of theories over the last four decades in early reading, set out by Tunmer and Hoover (2019). This framework shows how knowledge of a the lexicon of a language, coupled with its grammar structures, with syntax, fit the model of systematic initial reading instruction that stems from the 'simple view of reading' (SVR) (Gough & Tunmer, 1986) and its uptake as a model (Castles et al., 2018; Snow, Griffith & Burns, 2005; Snow 2018).

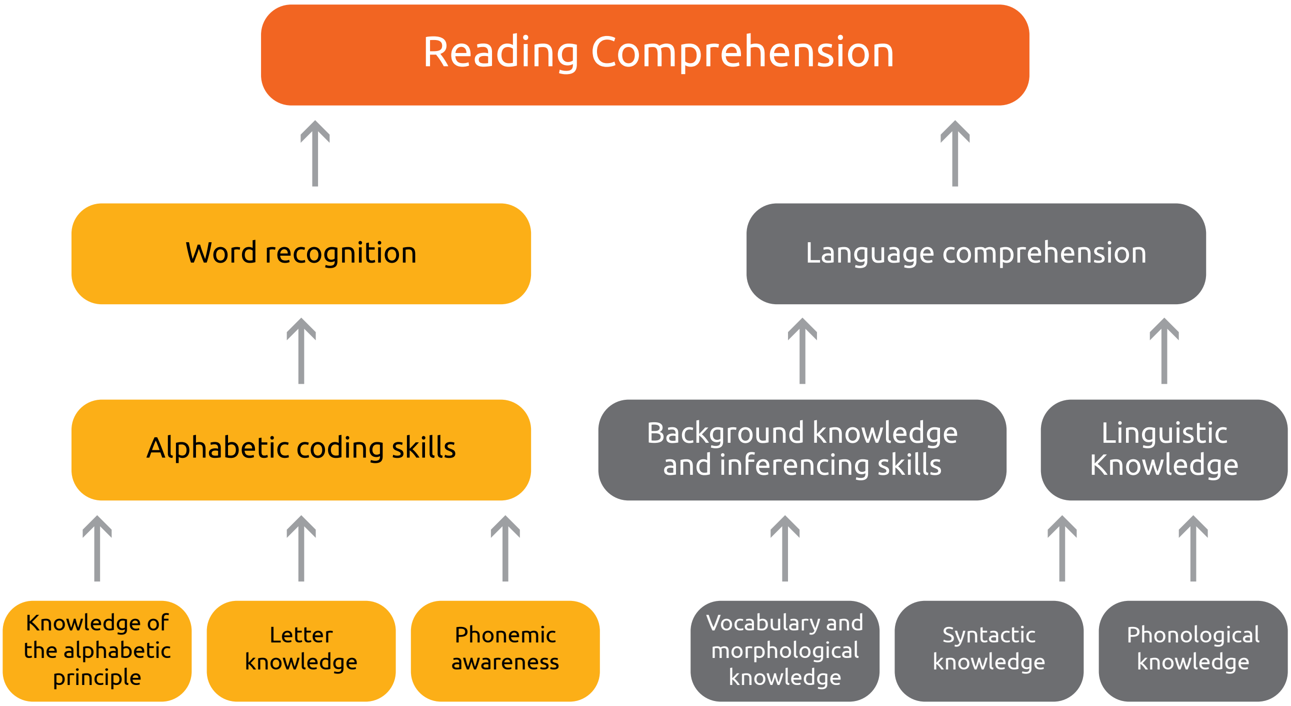

Figure 3: A framework for the cognitive foundations of learning to read (Tunmer & Hoover, 2019, p. 76)

Test Three: The Meerkat Maths Language Test MMLT)

In the introduction to a recent draft paper, Bezuidenhout (in press), who designed this instrument, reports:

> In a study of children's number concept development in the kindergarten year, it was evident, as several authors argue (Purpura and Logan 2015; Toll and Van Luit 2014), that children's mathematics-specific vocabulary turned out to be the primary indicator of achievement after one year – when the children entered Grade 1

This view is also proposed by Spelke (2017) in a proposal that natural language is the source of concepts more than cognitive evolution or culture. The argument that Dowker and Nuerk (2016) propose in this regard, is that known vocabulary is crucial for forming linguistically named concepts, much as was argued by Vygotsky (1986, 1978), who argued that there is a constant pattern of interaction between the development of concepts (such as number concepts) and the development of language, including vocabulary and linguistic structures such as syntax and morphology and that linguistic representation intersects with cognitive modelling (Kozulin 1990; Vygotsky, 1986). With this view in mind, namely that there is an interplay between the development of language and conceptual representations, we argue that young children rely on vocabulary that represents a concept as 'semiotic mediation' for learning (Henning & Ragpot.

2015; Vygotsky 1986). Because no mathematics-specific vocabulary tests existed in all the languages in which the children in the current project are educated, we used a custom-designed instrument of mathematics related vocabulary, originally constructed in English and translated into the languages other than English in the project schools.

Some other recent studies have also shown a relationship between mathematics and language (Davidson, Eng & Barner 2012; Negen & Sarnecka 2012; Purpura, Hume, Sims & Lonigan 2011; Romano, Babchishin, Pagani & Kohen 2010). A possible explanation for the relation is that frequent exposure to mathematics-specific vocabulary increases the chance of a child to develop an understanding of the conceptual properties of words (Dowker and Nuerk 2016), compared to a child who does not encounter such vocabulary often. Gopnik and Meltzoff (1997:208-209) argues that "aspects of linguistic input can have quite striking effects on conceptual development. Children who hear language relevant to a particular conceptual problem are more likely to solve that problem than children who do not". Studies have shown that both the quantity and quality of parents' (Gunderson & Levine 2011; Levine, Suriyakham, Rowe, Huttenlocher & Gunderson 2010) and teachers' (Klibanoff, Levine, Huttenlocher, Vasilyeva & Hedges 2006) 'number talk' influence the development of early number concepts.

Conclusion

Considering that the foundations for learning in the primary school are laid in the first few grades and that the Grade 1-year can be predictive of children's later progress, it is crucial that their teachers use suitable diagnostic tools to obtain reliable results. For the children in this project, it may be necessary that the project itself could provide resources for learning support. In integrating the results from the testing of the skills referred to in this paper, the composite picture of children's wellbeing and school progress could assist not only in the practice of social and educational care, but may have some utility value for policy briefs for the authorities that are responsible for children's learning, their development, and their overall wellbeing.[3]

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[3] The teachers in the sample schools of the present project will receive feedback on the results, coupled with several teacher development workshops, focusing on teaching tools for early reading and mathematics.

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