Language hurdles on the way to an understanding of length in early mathematics education

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Early mathematics education has been gaining more and more attention and importance in the domain of mathematics education research on language. The role of language, especially in early mathematical learning processes, is repeatedly emphasized. In this paper we present the complexity of linguistic difficulties for mathematical learning processes using the example of measurement and length, and illustrate aspects of such complexity with empirical data. In particular, we examine lexical, grammatical and semantical aspects.

Keywords: Early mathematics education, measurement, linguistic competence, oral language.

Introduction

Research in early mathematics education has shown the relevance of language for cognitive learning processes. Academic language proficiency is widely acknowledged as an important factor for successful education and schooling. Experts agree that academic language education processes should start as early as possible, be designed age-appropriately and be oriented to a specific content (Prediger, 2015; Rudd, Satterwhite, & Lambert, 2010). Unfortunately, the German school system is still in need for effective concepts to support children with disadvantageous starting conditions like migration, low socio-economic status or developmental speech disorder, in order to provide them with an equal chance to participate in (mathematics) education processes (Gogolin & Lange, 2010; Prediger, Renk, Büchter, Gursoy & Benholz, 2013). While most German preschool teachers seem to be aware of their function as language role models, only few have acquired a professional background that enables them to support interactive language learning processes (Ritterfeld, 2000). Michel, Ofner and Thoma (2014) examined German kindergarten teachers concerning their linguistic knowledge, their knowledge about children's language development and their ability to choose effective interventions. In this study only half of the questions, which experts see as relevant to foster language development in young children, were correctly answered. Isler, Künzli and Wiesner (2014) analysed conversations between Swiss kindergarten teachers and children in order to investigate the potential for the acquisition and fostering of academic language skills. Their results show that kindergarten teachers have to be made more aware of the central meaning of their language acts and to support a setup of practical action patterns for the fostering of academic language skills. Our research supports their findings since we find only few approaches for supporting children's language development in mathematic learning opportunities (Brandt & Keuch, 2017, in press). Based on these results, our aim is to raise preschool teachers' awareness for possible language hurdles, so that they are able to pay special attention to them in connection with supporting mathematical learning. Our objective is not to avoid these challenging language structures, but to use them in a way that fosters the children's language as well as mathematic development.

What we call language hurdles are first of all special features (lexical, syntactic or pragmatic) of academic German, a register often expected to be spoken but not explicitly taught at school (see Gogolin & Lange (2010) and Leisen (2013) for first approaches to integrate Academic German

language teaching in (mathematics) content teaching). Especially in pre-primary school settings, this means more than the usage of technical terms but also grammatical structures that enable children to grasp and express concepts. Furthermore, we look at characteristics that are hard to acquire for children with German as a second language or even first language. Finally, we are interested in words and expressions typical of a specific content. These features are analyzed with respect to the question whether they may impact on the understanding of a specific mathematic topic. For this specific mathematic topic, we choose measuring as one of Bishop's (1988) six basic activities and length as a magnitude that young children can directly perceive. Our aim is to figure out special features of the German language that preschool teachers can use as an opportunity to foster children's linguistic as well as mathematical development. Hence, we will first try to answer the following research question:

- Which linguistic structures (lexical, syntactic and semantic) can be problematic concerning the establishment of early concepts of length and how do preschool teachers deal with these problematic features?

Measurement and length

In order to answer the question above, this paper addresses measurement and the central magnitude length. Bishop (1988) claims that "measuring (...) is concerned with comparing, ordering, and with quantifying qualities" (p. 34). For the activities concerning measuring, an abstraction process is key, which results from a concentration on a quantifying characteristic. Real objects are compared regarding for example their length or weight, independent from their form, colour or other characteristics. The quantification of quality results from comparing with a unit, which is seen as a fundamental idea of all measuring activities independent from the magnitude. Here it becomes clear that talking about comparing, ordering and quantifying quality asks for a differentiated language usage, including technical terms and specific grammatical structures that are needed for example to describe a comparison or a quantification.

Many curricula for early mathematic education in Germany put emphasis on measurement. It does not only represent a link between mathematically abstract concepts and everyday life, but also comprises multiple inner-mathematical relations, especially with numbers and geometry (Barrett et al., 2011; Sarama, Clements, Barrett, van Dine & McDonel, 2011). Beyond, the concept of measurement can be seen as a basis for further concepts, for example fractions and rational numbers (Barrett et al., 2011). While we take research on the question how children acquire a (geometric) concept of magnitudes, which milestones children have to master and where they face mathematical difficulties (e.g., Sarama et al., 2011) as a background for our linguistic analysis, we will not discuss it in detail. In general, magnitudes like length and area are directly perceivable and accessible for young children. However, they are not easily to grasp because of their relations between each other and because children have difficulties to distinguish between them (Barrett et al., 2011; Skoumpourdi, 2015; Castle & Needham, 2007). Although an integrated approach for different spatial magnitudes, especially in early education, is seen as reasonable (Barrett et al., 2011) in order to understand the differences and the fundamental idea of measuring as comparison with a unit, here we only concentrate our linguistic analysis on length. Length belongs to spatial measurement. Piaget, Inhelder and Szeminska (1960) define the idea of special measurement in this way: "To measure (in Euclidean metrics) is to take out of a whole one element, taken as a unit, and to transpose this unit on the remainder of a whole: measurement is therefore a synthesis of sub-division and change of position" (p. 3). This change of position requires the understanding that (a) the size of the unit is conserved and (b) that the unit can be used iteratively. In doing so, the unit must be copied and repeated without a gap and without overlapping. Concrete objects become representations of length and their mutual characteristic is constituted in their one-dimensional linearity. The activity of measuring length concentrates on the determination of the

linear expansion. Therefore, you have to distinguish between objects with a rather clear linear characteristic, for example sticks or distances, and objects with more than one dimension that can be measured (width, height, depth) (Nührenbörger, 2002; Skoumpourdi, 2015). Consequently, it becomes obvious that speaking about length comes along with specific linguistic challenges, for example concerning the characteristic of linearity and the differentiation from area.

Language hurdles – Empirical examples

Our data is taken from Project erStMaL (early Steps in Mathematical Learning) (Acar Bayraktar, Hümmer, Huth, & Münz, 2011). The examples stem from seventeen group interactions with a preschool teacher and one to four children prepared and realized by the preschool teachers themselves. The videos were transcribed and annotated with EXMARaLDA (see http://exmaralda.org/en). Initially, our categories were deductive from research on problems in first and second language acquisition. In addition, we generated further categories inductively. By looking for signs of language awareness in preschool teachers, we detected a few situations where the teachers rather inhibit than facilitate mathematical as well as language learning. The wrong handling with some hurdles might lead to (partially) wrong concepts that could inhibit further mathematical learning. Other seem to be of importance only concerning language learning at first sight. Participating in mathematical negotiation processes, however, is seen as a main condition for mathematical learning.

Lexical aspects: Interferences

Research shows that when it comes to technical terms in mathematics, interferences are a specific difficulty, or rather learning opportunity (e.g., Abshagen, 2015; Lorenz, 2012). Interferences are a result of cross-linguistic influence (Lightbown & Spada, 2013), which means that two or more languages or two or more registers, respectively, interfere with each other. Depending on the languages or registers you look at, the amount and kind of interferences can vary. Mathematical language contains many words that exist in everyday language with a different meaning. This might lead to conflicts within the learner's mental lexicon. Maier and Schweiger (2008) call attention to the fact that learners might not consider words that they think they are already familiar with, and therefore miss the meaning of the word as a technical term. In the following example, the preschool teacher Barbara uses the word "point" ("Punkt"), which in German can be used in six different contexts (see https://www.duden.de/rechtschreibung/Punkt).

> Barbara: From THIS point here to the finger where I hold it, we had ONE meter [Von DEM Punkt hier bis zu dem Finger wo ich ihn festhalte, hatten wir ja EIN Meter]

A *Punkt* on the one hand is a small round spot that you might find in a polka dot dress. On the other hand, it can be not a concrete point but something abstract like a geographic point (*meeting point*) or a point in time. You can also *make a point* in an argumentation or reach a certain number of points in an exam. In German you say *einen Punkt erzielen* when you score a goal. While point in the sense of *scoring a goal* in sports is rather unlikely in this situation, it might not be obvious if Barbara is indicating an existing graphic dot or rather an imagined point in the sense of place or time. Since she does not seem to be aware of the ambiguity of her utterance, she misses a possible linguistic learning opportunity and might also aggravate the children's understanding of what one meter actually is. On another occasion, Barbara tries to explain the meaning of centimeter, while indicating the distance of one centimeter on a measuring tape with her fingers:

> Barbara: From one long line to the next, so just this little box yes? That's a … that's a centimeter there [Von einem langen Strich bis zu dem nächsten, also nur dieses Kästchen ja? Das ist ein … das ist ein Zentimeter da]

To explain the concept of centimeter with the word little box can be difficult for various reasons, as Kästchen (little box) can have various meanings in German (see https://www.duden.de/rechtschreibung/Kaestchen). First, it is the diminutive form for Kasten (box). However, *Kasten* again has several meanings. Most importantly, it can be either a three-dimensional object (a box to put things, like jewelry) or a two-dimensional square on a sheet of paper (*Tick a box*). Second and very prominent in school contexts, we have the meaning of *Kästchen* as a name for each single square on graph paper. Barbara might perceive the two lines that indicate where one centimeter starts or ends, and the boundaries of the tape as a little box. However, in this situation it is not clear if the children achieve a similar degree of abstraction.

Lexical aspects: Word formation

Abshagen (2015) mentions compounds and nominalizations as being difficult to understand for learners. There is a distinction between endocentric (the meaning of a compound word can be guessed by combining the meanings of its components) and exocentric compounds which obtain meanings that cannot be guessed by the combination of their components (Bieswanger & Becker, 2017). While the latter has to be learned as individual vocabulary, the former seems to be a plausible principle, even for young children. When one preschool teacher holds up a ruler (Lineal) and asks the children for its name, one boy calls it a Maßbrett (Measureboard) and intuitively constructs an endocentric compound. It is not the correct word in this context but resembles the names for other measuring devices like Maßband (measuring tape). Instead of using it as a learning opportunity, the preschool teacher ignores the word building process and says “That’s a ruler”. Nominalizations, however, are a kind of derivation and often emerge by adding a suffix (for example -er) to the stem of a verb (Bieswanger & Becker, 2017). Again, children implicitly seem to know this process, as the following example shows. A preschool teacher asks for the name for ruler (Lineal). When a girl with German as a second language answers Messer (knife, but also measure-er), the preschool teacher praises her answer with the words “good name”. Although it seems to be the wrong word at first sight, there probably lies a very interesting word building process behind it, which the preschool teacher at least subconsciously seems to notice und even appreciates it (for this example also see Brandt & Keuch, in press).

Lexical aspects: Measuring devices, measuring units and indication of size

In most situations, the preschool teachers measure the children‘s body length, name and record them in different ways. Some write them down, others document them with woolen strings (Brandt & Keuch, in press). When you capture body length with standardized measuring tools, you read the numbers on the measuring tools as a scale value. With measuring tools, the scale value indicates the corresponding measuring value based on a certain scale unit; for ordinary levelling boards or folding rules, that is centimeter. When using measuring sticks and folding rules, the kindergartners on the one hand are confronted with measuring units whose meaning they rarely comprehend and only hesitantly take over into their active vocabulary (Brandt & Keuch, in press). Moreover, they also have to deal with numbers that exceed their actively mastered range of numbers. Some preschool teachers become very creative when trying to make these numbers more accessible for young children, like Sabine in the following example:

Sabine: And you are exactly as big as this red number [Und du bist genau so groß wie diese rote Zahl ist]

On the folding rule used in this situation, the scale values are marked in red for every ten centimeters, while all other numbers are black. The red number therefore references the measured body length. Sabine syntactically uses the red number as a representation for the measured size value 110 centimeters. In the passage before, we could show that children become very inventive when it comes to naming standardized normed measuring devices. In Brandt and Keuch (2017) we show how children particularly struggle with objective non-normed measuring devices. After

having used building blocks to measure a child's body length, one of the children takes a piece of chalk and says: "I measure it with the chalk" ["ich messe mal mit der Kreide"]. What he actually does, however, is drawing a line on the floor between two marks that the child's head and feet. In this situation, the preschool teacher could have taken up this utterance by showing that you can measure a distance with a piece of chalk, but just by drawing a line on the floor. Unfortunately, the preschool teacher does not comment on Can's utterance or actions.

Grammatical aspects: Valence

In Brandt and Keuch (in press) we analyze the grammatical valence of the verb *measure* in oral language. The term valence derives from chemistry, where it describes the ability of an atom to link with other atoms. Linguistics takes this model to explain the fact that in valence theory, a verb asks for a certain number and kind of sentence constituents (like subject, different objects or adverbial phrases) in order to form a correct sentence (Herbst & Götz-Votteler, 2008). The addition as well as the omission of constituents might lead to different meanings or even incorrect utterances. The verb "measure" asks for a subject (someone who measures) and an object (something or someone that is measured). Often, you also have an adverbial phrase that tells you the measuring device used (with what you measure). When one preschool teacher asks a child to stand back-to-back with another girl and compare their sizes, she accompanies her request with the words "Do you want to measure yourself with Sadira?" ["Willst du dich jetzt mit der Sadira messen?"]. By adding the reflexive pronoun *yourself* [*dich*], the teacher (probably involuntarily) changes the meaning of the verb and literally asks for a competition, but not necessarily a measurement (Brandt & Keuch, in press).

Semantic aspects: Conventionalized expressions (Phraseologisms)

Another aspect that has been neglected for a long time are so called phraseologisms, in this case a combination of words or a functional unit whose meaning cannot be solely deduced from the combination of the single words (Cowie, 2001). Experts agree that the acquisition of phraseologisms demands special strategies that only develop during primary school (Buhofer, Burger & Sialm, 2012) and that it constitutes as a hurdle especially in a second language (Granger & Meunier, 2008). In the following example, a preschool teacher uses the formulaic expression "back to back" to ask the children Deny and Can to compare their height:

Barbara: Get up both, back to back, back to back, BACK to back, so [Steht mal beide auf, Rücken zu Rücken, Rücken zu Rücken, RÜcken zu Rücken]

After being asked to stand up and to stand *back to back* for the first time, Deny and Can stand behind each other, Deny's face is facing Can's back. Barbara stands up while repeating the phrase repeatedly without any reaction from the boy. Studies about the acquisition of phrases have shown that these idiomatic expressions are not solely conceived by steady repetition. Learners rather have to deduce the meaning of phrases from the context in the particular situation (Häcki Buhofer, 1997). In this short extract, it becomes obvious that the children do not understand the utterance despite Barbara's repeated articulation. The action she asks for becomes only clear when she touches Deny's shoulders and turns him around so they can compare their height.

Conclusion

The literature concerning first and second language acquisition shows many starting points for possible linguistic barriers that can used as learning opportunities. In this paper, we have first tried to choose the ones that might be important concerning the development of an understanding of length from a theoretical point of view. Examples from our empirical data supported our categories. It became obvious that some preschool teachers are able to use these difficulties productively to create possible learning opportunities. On the other hand, there are also preschool

teachers who, with their situative language usage, reinforce difficulties concerning language acquisition as well as the understanding of length. Further desiderata of our study are to systematize these difficulties and to apply them to other magnitudes in order to raise awareness for difficulties and hurdles when dealing with language in mathematical learning situations.

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