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About real-world contexts in mathematics education and their impact on language and learning

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In mathematics education real-world contexts are frequently used to catch the students' attention and to foster their understanding of the learning content. Presumably, especially in primary school they are used with the aim of building bridges between the familiar 'everyday world' of the students and the more formal and abstract 'world of mathematics'. The presented study questions the meaningfulness of real-world contexts in mathematics lessons in primary school and reveals some limitations of them. Interactional analyses of selected passages of mathematics lessons will illustrate some scenes with real-world contexts and their impact on language use and the opportunities to learn.

Keywords: Context effect, interaction analysis, language styles, primary school, teaching methods.

How this study came to its focus – Research goals, questions and methods

One fundamental theoretical assumption of this research project is, that the use of language differs concerning the situation. Taking into account the sum of linguistic events taking part during (mathematics) lessons could help considering language as “a complex meaning-making system” (Moschkovich, 2018, p. 39). Recognizing that people participate in different manners during varying situations the central purpose of this study is to examine language use during different situations of mathematics lessons. Findings about the situatedness of language within the mathematics classroom will be significant for teachers and designers of text books as they can be sensitized for specific language-based particularities of establishing a real-world context and, as a result, use different didactic approaches during different situations. Of the multitude of language-influencing factors – like the social formation, the (non-)existence of the teacher, happenings before the situation, the participants' aims and experiences, and many other –, during the observations I recognized scenes in which language use and its impact on the participants' supposed opportunities to learn were of a special character: Especially in the observed primary school mathematics lessons, the mathematical content was frequently and in different manners connected to a real-world context. Derived from the main question about how language use in mathematics classrooms changes depending on the situation – what could be hardly answered by a single dissertation project –, the focus is on how the “‘pure mathematics’ task [is] dressed up in a real-life context” (Palm, 2006, p. 46), what led to the question:

Q1: How does the use of language look like when the mathematical content is 'dressed up' or connected to a real-world context?

The first research question aims to give answers about how language use might differ from other classroom situations when teachers (and mathematics textbooks) connect mathematics to the students' supposed real-world experiences. For example, it might happen that language is less explicit and formal and, instead, tends to be imprecise, context-bound and less mathematical. Another important aspect is the impact on learning mathematics. A central assumption of the presented study is that different situations create different possibilities of using language and, as a result, also create different demands to the students which form of language is seen as the 'more appropriate' one in the

current situation. As the presented research project is situated in *interpretative classroom research* and *symbolic interactionism*, we take up a social-constructivist view on learning: Here, learning is seen as a collective and interactional process (e.g. Blumer, 1969; Cobb & Bauersfeld, 1995). In this regard, differences in language use result in different opportunities to learn and to participate within the mathematics classroom. From this the following question can be derived:

Q2: Which language-based opportunities and requirements and which opportunities to learn mathematics go along with the use of real-world contexts and learning material?

As one is not able to look in the students' heads and to make definite statements about their progress in learning, the second research question does not aim at giving absolute and complete answers about arising learning opportunities. It is more about giving tentative assumptions about how the connection of the mathematical content and a real-world context might affect the opportunities to learn.

To gain a broad impression of the language use during different situations, mathematics lessons of several classes (different school types and different class levels as well) have been video-recorded during the period from March 2017 to May 2018. The duration of the recordings in each class varies from two to four weeks (just mathematics lessons). For each observed class there are at least six video-recorded mathematics lessons which follows each other. Selected passages were transcribed and analyzed with the use of interactional analysis. One fundamental assumption of this approach is

that meaning is negotiated in interactions between several individuals and that social interaction is thus be understood as constitutive of learning processes, speaking about mathematics with others is in itself to be seen as the 'doing' of mathematics and the development of meaning (Schütte, Friesen, & Jung, 2019, p. 104).

Following this, social interactions are at the center of attention and the 'place', where (mathematical) meaning is negotiated. After setting and structuring an interactional unit that should be analysed in detail (here, these are scenes where the mathematical content is connected to a real-world context) a further step is to give a general description of the scene and to make a detailed sequential interpretation of the individual utterances. This detailed step-by-step analysis helps to look at the transcript scene in detail and to reconstruct the development of the interaction and is often interwoven with the turn-by-turn analysis, where some interpretations of the sequential analysis are regarded as more or less applicable interpretations of an utterance. Finally, the summary of the interpretation helps to reduce the diversity of the interpretations that were made before and illustrates only these interpretations, which can best be justified (for a detailed English description of the approach, its basic concepts and analysis steps see Schütte et al., 2019). For reasons of space, the analysis below is limited to the first and last step of the interactional analysis: A description of the scene and summary of the interpretations. Beforehand, it seems important to take a closer look at real-world contexts.

Real-world contexts as bridges and obstacles for learning

Although this paper makes use of the term *real-world context* there exist a number of similarly used terms (like narrative, real-world connection, storytelling, word problem, or story problem) and there is a lack of an established and universal specification of the term (Gainsburg, 2008; Larina, 2016). Additionally, a range of different activities can be called a real-world context in mathematics education: From classic word problems and analogies to the discussion of mathematics in the

community, the analysis of real data, or processes of mathematical modeling (Gainsburg, 2008). In this context, Larina (2016) also underlines that because of the missing universal definition but simultaneously the continuous claim to use real-world problems, teachers are guided by their own criteria for the selection of them. Within the frame of this paper, the term real-world context is used to refer to a – more or less explicit – connection between the formal symbols and procedures of mathematics on the one hand, and activities, objects and actions from the world we are living in, on the other hand.

There are beneficial and limiting aspects of conducting a real-world context in the mathematics classroom. Previous studies document, that teachers connect mathematics with real-world with the aim of enhancing the students' understanding, motivate them to learn mathematics and to participate in the mathematics lesson, and to help them applying mathematics to real problems (e.g. Boaler, 1993; Gainsburg, 2008; Sullivan, Zevenbergen, & Mousley, 2003). In this regard, real-world contexts have the potential to be viewed as a *bridge* between mathematics and real world. For many – children as well as adults – the abstractness of mathematics is a synonym for a detached, inflexible and cold body of knowledge. Through the use of real-world contexts, the mathematical task becomes more subjective and personal in order to get involved with mathematics more easily (Boaler, 1993).

Despite the high variety of approaches in establishing a real-world context in the mathematics classroom and the potentials named above, research suggests that they are used infrequently and cursory (Gainsburg, 2008). Often, especially the presumably most common form of real-world contexts – word problems – come from textbooks and less from the teacher him- or herself, what might rather cause fuzziness than enlightenment and does not open the usage of the underlying mathematical content for real-world situations (Crespo & Sinclair, 2008). Greer (1997) and Nesher (1980) point out the stereotyped nature of their presentation: an unrealistic numerically clean nature including all necessary data; single-step and narrow story problems; superficial features like keywords; the fact that they seem to be always-solvable in only a single way; or the direct match with exactly one operation or mathematical concept (see also in Crespo & Sinclair, 2008; Gainsburg, 2008; Zan, 2017). These shortcomings often result in an unreflected treatment with the mathematical content within the presented real-world context: Students become trained in solving a context task exactly in the expected way. They often believe what they are told without questioning the distance of the mathematical task from reality (Boaler, 1993). In this regard, many students could not sufficiently identify with the presented real-world context, as they had no contact with them before (e.g. paying bills and wage slips); or they fail to recognize the purpose of the task and the mathematical content within (e.g. Boaler, 1993; Sullivan et al., 2003; Zan, 2017). Taking also into account these aspects, real-world contexts could be also seen as *obstacles* for understanding mathematics and recognizing the usefulness of mathematics for life. Following Sullivan et al. (2003), teachers need to develop a certain sensitiveness and should be able to make judgements about the use of contexts. This concern, for example, the (mathematical) suitability, the relevance to the students, the potential motivational and emotional impact, and even the possibility of negative effects for the students' opportunities to learn.

Considering the related literature, many studies and literature reviews focus mainly on the usage of real-world connections in higher grades (e.g. Gainsburg, 2008) – but especially in *primary school* we

expect a more frequent (and different) usage of real-world contexts and that the relation between the everyday world and mathematics could be problematic especially for young students: While the everyday context is mostly unquestionable and plausible for them, the world of mathematics seems to reveal a ‘new way’ of thinking about this everyday world, as nearly everything could be the topic of a mathematical task (Neth & Voigt, 1991). Presumably, especially primary school children take the presented real-world context too much into account and fail to identify the mathematical content of it. While the teacher who presents the real-world context puts his or her focus on the mathematical content, the students might think more directly and emotional with connection to their world experiences (Neth & Voigt, 1991). In this regard, the use of real-world contexts for illustrating a mathematical content could have consequences for the use of language and the opportunities to learn mathematics as well, as the presented scenes below will illustrate.

Research example “A real circle in mathematics” versus “Our circle in here”

Within the frame of this paper, the focus is on one scene from a geometrical topic in which the teacher explicitly asks the students about differences between mathematics and an example from the real-world. In this second-class mathematics lesson the teacher starts the topic (circles and circle patterns) by forming a circle of people with the whole class around some desks in the classroom (see Figure 1). Additionally, she also prepared a circle with diameter, radius and center on the board before the lesson begun (see Figure 2). She opens up the comparison of a ‘real circle in mathematics’ and the circle of humans in the classroom (“...our circle in here...”) and starts the discussion as follows:



Figure 1

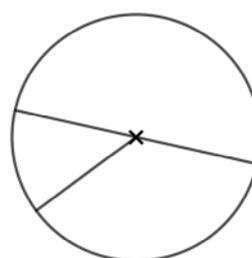


Figure 2

Teacher: now here we have a circle and we say this is a circle\ and certainly for a real circle in mathematics there are some requirements\ these we have already learned right/ and/ . maybe we we could collect them together\ . why is this not a real circle in mathematics/ I am curious if we already know this and have memorized it\ Matty is allowed to tell what is missing here\

Matty: the round edges there are missing a bit here\ like this the round ones [shows along the circle of humans]

Teacher: the . yes\ how is this called in a circle/ . I have brought up this question once already\ what do we call this all the way round a circle/ a /

Eddy: erm at the moment this [pointing along the circle of students] is rather a rectangle

Teacher: yes\ this is not a circle\ we only say this is a circle for us ok/ but in mathematics this is not a real circle\ . . what is a real circle/ what is missing here/ how does this looks

in mathematics what we are forming now in here with the children/ [goes to the board and points at the circle line]

3 Students: an oval

Teacher: . . actually we are forming the circle/ line\ because we closed the circle with our hands\ so . and why is this not a real circle yet/ what is still missing here/ Polly\

Polly: well but the the desks are also standing around that way .. so all in all this is a quadrangle\ [pointing on the desks in the middle of the human circle and then painting a circle in the air with her hand] one cannot form a circle here\

Teacher: why not\ . we now could stand in a way that it will be exactly a circle\ ..why can this never be a real circle as in mathematics/

Eddy: erm every time when we are touching each other like here for example there is an edge backwards when one is doing this [pats slightly on the wall behind him and his left partner with both their hands while they hold each other]

Teacher: yes this is ok\ now let us pretend we are the circle line\ but what is still missing/ we do not know if this is a real circle line . Nock

Nock: there is too less space .. one rather could make a zig-zag line. it could never become straight\ . or it should be equal on all sides\ so not that there stand less and on the other side many more

Teacher: then we do it like this/ we imagine that we are all points on the circle line\ .. maybe you will get it\ . is the distance the same everywhere/

In this example the real-world context was established at the beginning of a new (sub-)topic in the first minutes of the mathematics lesson. For a better structure, the analysis is organized in two areas: (1) Characteristics of the use of language, (2) and the assumed opportunities to learn. As it is hardly possible to make certain statements about what the students have learned, this part of the analysis is limited to *assumptions* about learning opportunities that could arise (Schütte et al., 2019).

(1) Concerning the use of language, we could identify some meaningful points about establishing the comparison between different types of circles: In the presented situation this leads to an indefinite and ambiguous use of language. By opening up the contrast between ‘a real circle in mathematics’ and ‘our circle here ... this is not a real circle’ the teacher implicitly points out, that there exist two (or even more) different kinds of circles which differ depending on the context. She also indicates, that only the mathematical circle is ‘a real circle’ while the human one does not fulfill the same (mathematical) requirements. Presumably, the teacher intends to repeat some important characteristics and terms of a circle like ‘radius’ or ‘middle point’. But the students’ answers seem more to refer to the question, why this (human) circle is not a ‘real’ circle and less to the necessary requirements a mathematical circle has to fulfill. The visual and haptic existent circle of humans could help them to participate in the class discussion (for instance, by referring to it through deictic expressions or a contextualized use of language). Maybe because of this, their utterances seem to be oriented to the visual and haptic human circle in the classroom. They use deictic expressions instead

of a decontextualized language that includes mathematical technical terms like ‘circle line’ and ‘radius’. Accordingly, the ‘place’ of the ongoing classroom discussion is somewhere ‘between’ mathematics and everyday world, as neither the connection of both types of circles nor the teachers’ goals were made explicit. The ongoing classroom discussion seems to be less a mathematical oriented discourse about a circle than on a quiz about differences between the ‘real’ and the human circle. The students seem to play two different roles in this scene. First, they could be regarded as part of the real-world connection, as their bodies shape the human circle. Through their individual position within the circle, everyone has a different view on the scene. Second, they are actors in the teachers established “playful” introducing performance of collecting characteristics of a mathematical circle, as they are asked for their ideas and already existing knowledge. This might also affect their language use.

(2) Through visualizing a circle the learners’ knowledge is recalled from their memory. But we could question if the circle of humans or the dichotomous distinction between two different kinds of circles is the source of misconceptions and misleading statements of the students. As through the learners’ utterances we cannot make a definite and confirmed statement about their orientation (either to the formal mathematical circle or to the human circle) we can only assume, that they are aware of the characteristics of a mathematical circle. That is the regularity and ‘smoothness’ of the circle line, and the non-existence of edges and irregularities. The reasons for the students’ ‘less mathematical’ answers could be diverse: First, the teacher simultaneously asked for two aspects (characteristics of a ‘real circle’ versus why is this not a ‘real circle’) and they are referring to the second and maybe more easily one. Second, the visual and haptic existence of the human circle ‘grabs’ the students’ attention too much. Third, the teacher did not make explicit, which question is the more important one and that the students have to tell technical terms of a mathematical circle. Unfortunately, the teacher only seems to realize her own script of the lesson. And this is about the words “circle line, middle point and radius”, as her closing words for this scene illustrate: “The radius is, so to speak, the bar between the middle point and the circle line and has to be equal everywhere. And if we do not have a middle point we do not know if we all stand in the same distance to the middle point”. It is questionable, where the discussion might lead, if the teacher does ask the students about the similarities of the human and a mathematical circle. Maybe then the teacher might rather identify the mathematical important and correct aspects in the students’ utterances. Additionally, a circle can also be defined through optical aspects like the circle lines’ regularity but the teacher seems to assume only the technical terms as necessary characters for a (mathematical) correct definition of a circle.

Putting the mathematical content of the formal characterizing aspects of a mathematical circle in relationship to the circle of humans lead – this is our assumption – to differences in *definitions of the situation* (Schütte et al., 2019) between the teacher and the students. And in result, also to irregularities and ambiguities in language use. With better competences in interpreting and more sensitivity to the mathematical in the students’ answers, the teacher would be able to better comprehend and connect their utterances with her own expectations and with each other.

So no real-world connections?

Considering the impact of real-world contexts in mathematics primary school classrooms for language use the presented scenes illuminate the following: At first glance, the language seems to be

less mathematical and academic. Rather, one would say it is like informal everyday language and without a close connection to school mathematics. This seems to be mainly affected by the established real-world contexts, as the participants are able to directly refer to it and their own experiences. Additionally, the scenes illuminated a high frequency of deictic expressions and gestures that were used instead of ‘concrete’ and technical verbal expressions. The teachers’ language is a mix between the real-world context (mainly expressed through less technical and less academic words) and the underlying mathematical content (mainly expressed through technical terms of mathematics) without explicitly expressing the connection between both. Taking a closer look (e.g. with the help of interactional analysis), we could also identify the mathematical meaning in the teachers’ and the students’ utterances. Especially the first scene shows clearly, that teachers need competences in interpreting their students’ answers, as all of them contain the mathematically relevant idea of a circles’ regularity. Teachers should be aware, that they should be a linguistical example for the students on the one hand (and therefore use technical terms and a more formal and academic language register), and that the mathematical content should be specific and relevant for the students on the other hand (e.g. through real-world contexts that are mainly presented in a more informal and everyday language register).

With the help of interactional analyses of the presented scenes we can also assume the following effects of the real-world contexts on the students’ opportunities to learn mathematics: As the connection between the established real-world context and the mathematical topic was not explicitly expressed by the teacher, this could end up in students’ misconceptions and misunderstandings of the mathematical content. In some way, the presented real-world contexts rather seem to be a ‘decorative mask’ of the mathematical ‘core’, than a necessary tool to explain it. Additionally, the construction of an adequate representation of the real-world context and the mathematical problem could be more difficult for the students, than its solution (Zan, 2017). In this regard, teachers, teacher educators and the designers of mathematical textbooks should question the usefulness and necessity of real-world contexts critically. In both presented scenes, we see inhibitory aspects for the students’ opportunities to learn mathematics and implicit norms (see also Zan, 2017).

Shall we end up in the resulting conclusion about not establishing real-world contexts in mathematics lessons? In view of the fact, that we could identify positive as well as negative aspects of their application, this answer has unambiguously to be *no*. Especially in primary school, connecting the learning content and the students’ experiences from their real-world is considered as a central method. Regarding the use of language and the students’ chances to participate in the classroom discourse, real-world contexts are viewed as creating familiarity and reducing inhibitions. Nevertheless, teachers need to be sensitive about the usefulness of real-world connections, and, in result, also to aspects of language use and opportunities to learn.

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