What characterizes quality of mathematics classroom interaction for supporting language learners? Disentangling a complex phenomenon

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The crucial role of the quality of classroom interaction is highlighted in many qualitative studies, especially in connection with research on fostering (language learners') conceptual understanding of mathematics. But what exactly characterizes quality of classroom interaction? We want to address this question with the aim of proposing different criteria and disentangle the complex phenomenon into the talk-related, discursive, conceptual and lexical dimensions of the interaction. Therefore, we give an overview on related qualitative studies and deduce categories for the quality of classroom interaction for both, teachers' measures for activating students and for students' participation. This disentangling can establish a theoretical foundation for future research, as it provides directions for an operationalization for quantitative video-ratings.

Keywords: Classroom interaction, quality, activation, participation.

Why to operationalize quality of classroom interaction that can support language learners?

There is a wide consensus that language learners' (i.e., learners still acquiring the language of instruction) access to mathematics should be supported in specific ways (Gibbons, 2002; Moschkovich, 2013; Smit, van Eerde & Bakker, 2013). However, different instructional approaches exist which vary heavily in their main principles and quality criteria. For example, some researchers mainly focus on simplifying the mathematical texts (e.g., Haag, Heppt, Stanat, Kuhl & Pant, 2013), on training vocabulary (DfEE, 2000) or general reading strategies (Hagena, Leiß & Schwippert, 2017). Although these instructional approaches have been criticized for being too reductionist (e.g., Moschkovich, 2013, 2015), they persist being empirically investigated, especially in quantitative intervention studies. One reason might be that for these kinds of approaches, the criteria for successful implementation can easily be given.

In contrast, most mathematics education researchers emphasize that classroom interaction must be taken into account with respect to students' participation in rich discourse practices (Barwell, 2012; Erath, Prediger, Heller & Quasthoff, submitted; Moschkovich, 2013, 2015). Many qualitative studies (e.g., Erath et al., submitted; Moschkovich, 2015) highlight that the quality of communication and discourse is crucial for learning mathematics, especially for language learners. However, the quality of interaction is characterized in different ways without a systematic disentangling of the complex phenomenon. This might be a reason why so far, no quantitative studies exist which really provide quantitative evidence that high discursive quality can indeed impact on students' learning gains.

In our mainly theoretical paper, we try to systematize existing approaches and refine the construct of quality of interaction in a way that allows a later operationalization also for quantitative purposes. For this, we pursue the following research questions: *How can the quality of interaction*

in mathematics classrooms be disentangled into distinguishable dimensions? How can they be operationalized for quantitative video-ratings?

The questions are posed in the context of the intervention study MESUT, where students' conceptual understanding of fractions was fostered in a content- and language-integrated remediating intervention. Grade 7 students worked in groups of 3 to 6 with a teacher so that the interaction quality of 19 groups working with the same (conceptually focused) teaching material can be compared.

Theoretical background: Different dimensions of high quality interaction

Investigating the role of communication for learning mathematics has a long tradition in mathematics education research. Whereas large quantitative studies (e.g., Haag et al., 2013) point out that students with low language proficiency are outperformed by students with high language proficiency in mathematics tests, qualitative studies focus on analyzing learning processes and the related interplay of language and learning mathematics. In the following, we outline some of these studies with the aim of identifying different important dimensions of high quality interaction, especially with respect to supporting language learners.

The importance of giving students space for active participation in mathematics classroom discussions was already underlined twenty years ago, e.g., in Yackel and Cobb's (1996) qualitative study on social and sociomathematical norms. They argue how students' increased participation in the talk influences mathematical learning opportunities. This *dimension related to the quantitative amount of students' talk* (in brief: talk-related dimension) of quality of classroom interaction is also highlighted by other studies, e.g. underlying the TIMSS video study (Hiebert et al., 2003).

For learning mathematics, of course not only the quantity of talk but especially its *quality* matters. In their research overview, Hiebert and Grouws (2007) present quantitative studies which provide evidence for the effects of high quality teaching on students' learning gains. One major feature of high quality teaching is the focus on conceptual understanding. Most qualitative studies cited see alignment of a focus on conceptual understanding and high quality of discourse. This *conceptual dimension* is lately further investigated by Erath (2017) who points out that on the one hand especially explaining and arguing are linguistically more demanding than reports or descriptions but on the other hand these challenging discourses are connected to talking about conceptual knowledge (Hiebert & Lefevre, 1986) and thus are important discursive practices for a meaningful learning of mathematics.

This work builds a bridge to another perspective on the quality of communication in mathematics education research. The *discursive dimension* emphasizes the importance of rich discourse practices for fostering (language learners') mathematical understanding (e.g., Barwell, 2012; Erath et al., submitted; Moschkovich, 2015). It important that students participate in classroom communication processes but also that they are supported and encouraged to contribute to discursively rich communication about mathematics, which particularly means to avoid students' answers on single word level. That is, students' participation in discourse practices is seen as especially important for their mathematical learning. For carving out different dimensions of quality of interaction, we distinguish discursively rich discourse practices such as defining, explaining meanings, arguing, from less rich practices such as telling, reporting procedures (justified in the context of Interactional Discourse Analysis in Erath et al. submitted). Thus, the discursive dimension in this study refers to episodes of the interaction in which rich discourse practices are made relevant which especially means, that students are demanded to contribute with more than single words or half sentences.

Language learners have special needs when it comes to supporting them in participating in classroom communication: As several studies show (e.g., Gibbons, 2002; Prediger & Wessel, 2013; Smit et al., 2013), these learners need additional support on a lexical level in order to facilitate participation in discourse practices like explaining, arguing, describing etc. This *lexical dimension* does not imply offering lexical means for their own sake, but to offer integrative lexical support, integrated in jointly discussing mathematics. Until now, it can only be hypothesized that the lexical and discursive dimension are especially important for language learners. Since this must be investigated empirically, we hope to contribute in closing this research gap with our planed quantitative study.

First steps towards disentangling quality of classroom interaction

Systematizing the literature review leads us to distinguish four dimensions for high quality classroom interaction which can later be operationalized in codings for video-ratings:

- The *talk-related dimension* refers to students' general space to talk: how much time does the teacher speak, how much is left to student talk?
- The *conceptual dimension* refers to the epistemic quality of the talk with respect to the forms of knowledge: how much is conceptual knowledge addressed and connected, how much procedural knowledge?
- The *discursive dimension* incorporates the discursive quality by valuing rich discourse practices like explanations, argumentations higher than one-word answers or simple reports of solution pathways and descriptions.
- The *lexical dimension* refers to the specific support which is required for language learners: How much learning opportunities are provided for lexical means which are required for the discourse practices, and how are they embedded in the discursive practices?

These dimensions are connected, but they are not the same, as a brief analysis of the following episode (cf. Erath, 2017 for closer analysis) can show. The transcript stems from a remediate intervention for weak seventh graders on conceptual understanding of fractions in the project MESUT (see above). After a rich activity of drawing fraction bars for equivalent fractions, the students are supposed to consolidate their experiences by explaining the pseudo-student's utterance "If I'm looking up, I'm portioning more coarsely!" as printed in the task in Figure 1:

22	Dennis:	I'd like to say something else
23	Teacher:	W, What would you like to say?
24	Dennis:	The numerator has split here, here is written eight and there four
25	Teacher:	The numerator?
26	Dennis:	Or the denominator, no idea, down there, I don't know what it's called
27	Teacher:	The denominator
28	Dennis:	Yes
29a	Teacher:	Exactly, and what the denominator um divided by two, right so in half, and what does it with the bar? [*points to the bar in the task, 8 sec. break*]
29b	Teacher:	Whereby do I see at the bar that down here, the denominator is eight and above four
30	Dennis:	Because above#
31	Rahmiye:	#It doubles
32	Teacher:	Yes what doubles? Explain it
33	Rahmiye:	The denominator
34	Teacher:	The denominator from, from top to bottom it doubles, well, and how do I see it at the bar?
35	Dennis:	Because the pieces are larger

36 Teacher: Exactly, how many pieces and this is related to your doubling or halving, how many pieces are then one piece? If I'm looking the bottom up

37 Rahmiye: Two

38 Dennis: Two

39 Teacher: Correct yes, two pieces, make one lar… um, make one large and this is what Kenan means with 'if I'm looking up I'm portioning more coarsely' […]

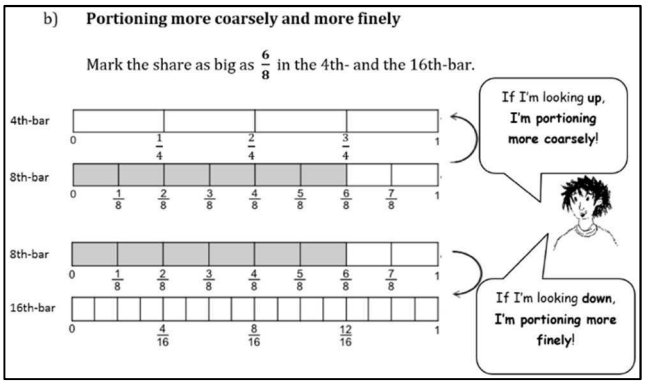

Figure 1. Task on the meaning of reducing and expanding fractions

In the *talk-related dimension*, the episode shows a high quality since the teacher initiates *talk-related activation* by requesting students' active contributions (Turns 23, 29, 32, 34) and students try to fulfill the demand by *talk-related participation*. The episode is also rich in the *conceptual dimension* as the task is intended to work on students' conceptual knowledge of connecting the new mental model for finding equal shares with the familiar representation of the fraction bar.

In the *discursive dimension*, the episode must be split into two parts: Until Turn 29a, there is a *discursive activation* by the teacher's request for explanations, but Dennis shifts his participation into a less rich discourse activity by describing the change of the written numbers rather than explaining their meaning. Hence, his *discursive participation* in rich discourse practices is more limited. In Turns 25 to 29a, the *discursive activation* is reduced for the sake of the vocabulary work, in Turn 29a, the teacher embeds his *lexical activation* into the discourse activity offered by Dennis. In Turn 29b, the discursive activation shifts again to the higher level of explanations, but students' participation stays very limited, as they mainly contribute single words. One exception is Dennis' utterance in Turn 35 which provides a more significant contribution to the discourse practice of explanation. In the same Turn 35, Dennis also participates in the *lexical* learning pathway as he adopts the meaning-related lexical means of pieces which become larger. The episode closes with the teacher fulfilling his own discursive demand for explaining the meaning of equivalent fraction. So he provides a *conceptual* learning opportunity in which the students participate more peripherally.

Table 1. Systematizing categories for quality of classroom interaction

	Talk-related dimension	*Conceptual dimension*	*Discursive dimension*	*Lexical dimension*
Teachers' intended activation	Space for students' talk in collective discussions of mathematics	Conceptual demands and meaning-related learning opportunities	High discursive demands by requesting rich discourse practices	Integrated lexical learning opportunities
Students' enacted participation	Participation in collective discussions of mathematics	Participation in meaning-related activities	Participation in rich discursive practices	Taking up lexical learning opportunities

This brief analysis suggests that the distinction of dimensions enables us to analyze their interplay. Within each dimension, it is crucial to distinguish between teachers' intended activation and students' enacted participation (Table 1). The quality of an interaction seems to depend on both.

A proposal for operationalizing different criteria for video-rating

Qualitative case studies of two data sets provide first indications that the discourse practices of explaining and arguing seem to be particularly important for working on aspects of conceptual knowledge and that only few students can participate in these sequences without the teacher's support (Erath, 2017; Erath et al., submitted). Furthermore, the teachers' moves seem to vary strongly in their impact on students' participation in the different dimensions (Erath, 2018).

Motivation for quantification

Based on these qualitative insights, a first quantitative case study (9 groups, 5 tasks) measured the talk-related and discursive activation and participation for individuals and groups (Nienhoff, 2017). The study reveals huge differences in the two dimensions on the group level and on the individual level. In addition, the individual share of (oral and written) explaining and arguing in time on task correlates to the measured learning gains (with $r = 0.331$) as well as a group variable: all students' share of discourse on the time on task correlated also to the learning gains (with $r = 0.318$). The latter finding suggests that listening in rich discursive learning environments can be effective for learning.

These first observations point to very interesting possibilities of quantitative analysis that motivate our attempt to operationalize the four suggested dimensions of classroom quality on an individual and a group level. Hence, based on the categories proposed in Section 3, our next step in future research is to search for operationalizing the categories for quantitatively grasping the quality of classroom interaction by video-ratings.

Operationalizing teachers' intended activation in four dimensions

For operationalizing the quality criteria in a video-rating, a basic coding was conducted on the tasks and the video data that allows determining frequencies: All tasks are categorized as having a lexical, conceptual or procedural focus as well as oral or written discursive demands that are further classified as sequencing (describing, reporting,…) or integrating (explaining, arguing,…). In the video data, the time spent on the different tasks (without time for general organization) is captured and can be summed up to the total time on task. Furthermore, the students' talking time is measured as well as more specifically students' and teachers' times spent on richer or less rich discourse practices as well as single-word utterances. Besides these time measurements, the teacher moves are classified as focusing discursive, lexical, conceptual or procedural aspects. For further investigating the lexical dimension, a simplified version of trace analysis (Prediger & Pöhler, 2015) is applied that relates the number of offered lexical means to those students' take up: More precisely, we count how many of the written offered formal and meaning related expressions are taken up by students in their oral utterances. This basic analysis allows specifying criteria for the quality of classroom interaction that relate to the four introduced dimensions of talk, discourse, conceptual knowledge, and lexical means.

The operationalizations of teachers' activation always refer to the small group, as small group characteristics determine individual learning opportunities, but not necessarily individual use:

- Criteria for the *talk-related activation* are operationalized as (CA1) the percentage of all students' talking time related to the groups' complete time on task and (CA2) as the percentage of time that the teacher is not speaking in the time on task, that operationalizes the

time for oral and written talk in whole group phases as well as in phases of working in pairs and individual seatwork.

- Criteria for the *discursive activation* are focusing the written or oral production of or contribution to discourse practices. On the written level, discursive activation is operationalized as (DA1) the percentage of time spent on writing tasks requesting discursive practices (including the time of orally reviewing these texts) in the time on task (for the whole lesson). On the oral level, two operationalizations are relevant: (DA2) grasps the percentage of time spent on discursive sequences of students and teacher together in the time on task, whereas (DA3) captures only the students' percentage of time spent on discursive sequences in the time on task.
- Criteria for the *conceptual activation* are proposed on the levels of tasks, teacher moves, and oral discourse: On the level of tasks, conceptual activation is operationalized (KA1) as percentage of time spent on tasks with conceptual focus in the time on task. On the level of teacher moves, it is operationalized (KA2) as percentage of teacher moves with conceptual focus in all teacher moves. On the level of oral discourse, conceptual activation is captured (KA3) as percentage of all students' time in sequences with integrating discourse in the time on task since qualitative studies point to the importance of these sequences (of explaining, arguing …) for the learning of conceptual knowledge whereas sequencing discourse (like describing or reporting) is more likely to be connected to working on procedural knowledge.
- Criteria for the *lexical activation* are suggested for tasks and for teacher moves: On the one hand, (LA1) operationalizes lexical activation as percentage of time spent on working on subtasks with lexical focus in the time on task. On the other hand, (LA2) operationalizes it as percentage of teacher moves with lexical focus in all teacher moves.

Operationalizing students' participation in four dimensions

In each dimension, students' participation is operationalized for each individual:

- Criteria for *talk-related participation* are operationalized (CP1) as percentage of individual talking time in the time on task and (CP2) as percentage of individual talking time in the talking time of all students.
- Criteria for *discursive participation* are operationalized (DP1) as percentage of individual time in discursive sequences in the time on task and (DP2) as percentage of individual talking time in the time spent on tasks demanding written texts.
- Criteria for *conceptual participation* are operationalized (KP1) as percentage of individual time in sequences with integrating discourse in the time on task and (KP2) as percentage of individual talking time in the time spent on tasks with conceptual focus.
- Criteria for *lexical participation* are operationalized (LP1) as percentage of the picked up terms and (LP2) as percentage of individual talking time in the time spent on tasks with lexical focus.

Outlook on the next steps towards a quantitative video-rating study

At the conference, we presented the suggested criteria and operationalizations for quality of interaction to the ETC participants and showed first results. Thanks to a lively discussion, we are in the process of refining our theoretical base and the operationalizations. In the future, we will be able to present empirical results based on these refinements and referring to a larger database: In a second study that is currently in the phase of coding, we refer to the video data of lesson 2 in 19 groups (one group from each teacher of the intervention; altogether 89 students). Lesson 2 was

chosen as a lesson with a lot of opportunities for communication. We are applying the operationalized criteria and are going to correlate them with the students' learning gains as difference between scores in pre- and posttest on the conceptual understanding of fractions.

We hope to find quantitative connections in the data because this would help to overcome the qualitative / quantitative divide in which the quantitative research always limits to less complex phenomena.

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