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HOW CAN TEACHERS PROVIDE LEARNING OPPORTUNITIES FOR ORAL EXPLANATIONS?

Kirstin Erath

TU Dortmund University

Explaining is one of the most important discursive practices in whole class discussions. The paper empirically reconstructs how teachers provide learning opportunities for students' oral mathematical explanations in videotaped classroom interaction episodes of a grade 5 class. By distinguishing the notions "enable participation", "support", and "foster", the learning opportunities are analyzed with respect to their influence on improving students' oral explanations.

THEORETICAL BACKGROUND

This paper reports a small explorative case study that aims at reconstructing learning opportunities for oral explanations in whole class discussions. It is based on a conceptualization of explaining as a practice of navigating through different epistemic fields, combining an interactionist perspective with an epistemic perspective (Prediger & Erath, 2014) and referring to research from discourse analysis (Erath, in prep.; by reference of Morek, Heller, & Quasthoff, in press). This allows conceptualizing explaining as a mathematical discursive practice that is interactively established in a classroom microculture while simultaneously bearing its mathematical character in mind. In this view, learning to explain means to increasingly participate in these established practices.

Communication simultaneously takes the role of learning medium and learning goal in the mathematics classroom: "learning to communicate as a goal of instruction cannot be clearly separated from communication as a means by which students develop mathematical understandings" (Lampert & Cobb, 2003, p. 237). The relevance of explaining as a linguistic learning goal is also reflected in many curricula and standards worldwide. It is deeply connected to mathematical learning goals as Moschkovich's (2015) definition of academic literacy in mathematics emphasizes. Moschkovich's construct of academic literacy prioritizes the discourse against support on lexical or syntactical levels: "One of the goals of mathematics instruction … should be to support all students … in participating in discussions that focus on important mathematical concepts and engage students in mathematical practices, rather than on low-level linguistic skills" (ibid., p. 2). An increasing number of researchers in mathematics education emphasizes this role of discourse for mathematical learning (e.g. Barwell, 2012). But so far, only little is known about how students learn to participate in mathematical discursive practices like explaining and which learning opportunities are offered to them. The presented study addresses this question by empirically reconstructing ways of providing learning opportunities for oral explanations in whole class discussions in a grade 5 mathematics classroom.

Explanations have a special position in mathematics classroom discourse. From a more general discourse analytic point of view, explaining acts as a tool for the construction and demonstration of knowledge (e.g. Morek et al., in press), thus two major functions of instruction. From an epistemic point of view, explaining in mathematics classrooms especially is used to communicate about connections between different pieces of knowledge. These connections are important for a meaningful learning of mathematics as for example Hiebert and Lefevre (1986) point out for the connection of procedural and conceptual knowledge. This shows the importance of explaining as a learning medium. Furthermore, frequency-analysis of four classrooms show that explaining is the most frequently demanded discursive practice (Erath, Prediger, Heller, & Quasthoff, in prep.). That is, explaining in whole class discussions is nothing special but very common in mathematics classrooms in Germany.

The case study of Erath & Prediger (2015) shows that students participate in remarkably different ways in these practices of explaining and epistemic participation profiles are empirically reconstructed: Whereas some students consistently take part in explaining contents with high cognitive demands, other students mainly contribute at the beginning of explanation sequences and do not contribute to the proceeding epistemic processes. The interrelation with an analysis of the students discourse competency (Erath et al., in prep.) shows that there is a connection between students' discourse competency and their epistemic participation profile and furthermore with mathematical learning opportunities. These results of the larger research-project INTERPASS show that students with lower discursive competencies might be disadvantaged in matters of learning mathematics. Therefore it is important to support all students in taking part in the explanations in whole class discussions and to give them the opportunity to learn how to explain mathematically. This especially applies to classrooms in secondary schools: Analyzing students' learning opportunities for learning to explain is crucial in grade 5 as linguistic research marks this age as essential for acquiring discursive competencies of explaining (Heller & Morek, 2015).

But how can teachers provide learning opportunities to participate in these kinds of mathematical practices and in this case in practices of explaining? The linguists Heller and Morek (2015) propose general ideas of teacher activities which support participation and learning on a discursive level like giving opportunities to meaningful explanations and argumentations, explicating discursive expectations, and working on and talking about exemplary contributions. Smit, van Eerde and Bakker (2013) introduce a conceptualization of whole class scaffolding and investigate scaffolding language in multilingual whole class settings from the perspective of mathematics education focusing on the domain of line graphs. They offer examples of strategies for scaffolding language and emphasize that scaffolding does not refer to single teacher activities but to observations across lessons. These two theoretical points of reference lead to the distinction of the three notions *enable participation*, *support*, and *foster* that proved crucial in the analysis of learning opportunities. *Enabling participation* means to give the students room for own explanations and thus the opportunity to practice their oral explaining. *Support* and *foster* both describe teachers' moves that help students to explain but on different times scales. A situative *support* is given in a specific interaction situation, possibly without focus on handing over independence in the long run (Smit et al. 2013 are referring to this phenomenon as "online responsiveness"). It aims at helping students to situatively overcome problems with a certain explanation, i.e. the teacher supports them in explaining the questioned mathematical content. *Foster* on the other hand refers to teachers' moves that intend to improve students' explanation skills in the long run, i.e. these moves aim at extending the students' discursive competencies. This category resembles the notion of "online handover to independence" (Smit et al., 2013).

DESIGN AND METHODOLOGY OF THE STUDY

In the larger project INTERPASS (cf. Prediger & Erath, 2014) video data was gathered in 12 maths lessons of five different grade 5 classrooms each. For the 55 h video data, all whole class explanation sequences were transcribed and analyzed with respect to different research questions (Prediger & Erath, 2014; Erath & Prediger, 2015; Erath et al., in prep.; Erath, in prep.).

The small explorative case study presented in this paper builds on video data from one higher tracked class in an underprivileged urban quarter with many second language learners. This class is chosen since the teacher is very sensitive to language and a lot of students' explanations can be observed. For this case study, all classroom sequences in which a calculation was to be explained by means of conceptual epistemic fields were investigated since this kind of explanations is important for meaningful learning of mathematics from an epistemic point of view; six sequences matched this criterion.

For the data analysis with respect to this paper's research question 'How can teachers provide learning opportunities for oral explanations?', the teacher's moves and reactions were analyzed in regard to their potential to (1) enable students to participate in the explanation, (2) support students during the explanation, (3) foster students in order to improve their explanation skills.

RESULTS: RECONSTRUCTED WAYS OF PROVIDING LEARNING OPPORTUNITIES FOR ORAL EXPLANATIONS

Several ways of providing learning opportunities for oral explanations can be reconstructed in the six analyzed sequences. Some of them can be observed several times, some infrequently, probably due to the small number of sequences. The following sequence "per person" from the middle of the schoolyear is used to exemplify the different ways (the transcript was translated from German and simplified). In the sequence, the students explain how to calculate the costs per person for a guided tour if a tour for 10 persons costs 30 Euro and 29 students are in the class.

6	Uwe	So if you now um so such a guided tour costs 30 Euro altogether for ten persons;
7	class	I see, I see!
8	Uwe	(…) normally you have to divide 30 by 10 that you for one person the guided well no one does that but for if you for the guided tour so if one wants to do a guided tour it costs point point point Euro for one
9	tea	3 Euro would that be then
10	Uwe	Yes
11	tea	If you divide that by 10, right? Hm_hm it's not yet one hundred percent correct; if you are really very accurate this time; how much money do they have to spend for guided tours if they go there as a class of 29? Malte;
12	Malte	90 Euro;
13	tea	How do you figure out the cost per individual student? Malte;
14	Malte	You have to 90 divided by 29
15	tea	*((writes on the blackboard:* 90*))*
16	Ali	but why 90?
17	Mia	why 90?
18	tea	Malte tell again; *((writes:* :29*))* why 90? Man, it's after all 30 Euro for a guided tour;

19	Malte	Well because they are abou they are 29 children? And per guided tour go well 10 children join; and that's closely near the 30 and suits then we can do 3 guided tours and then we even have one place with it.
20	Monir	I still didn't get it;
21	tea	Who did who can who can explain it again; Monir says the thing with the guided tour; but I think it's the most difficult point with the guided tour; Who can again tell us something about that? Kain, Dilay;
…		
24	Dilay	So he did round the 29 to 30 and then he did 30 times 10; because it costs 30 Euro and um for on
25	tea	30 times 3; happend accidentally?
26	Dilay	Oh yes 30 times 3; did 3 30 times 3; und this makes 90;
27	tea	Because they need 3 guided tours; Well they are 29 students and they only may take a maximum of 10; with the first guided tour 10 are away, with the second it's 20 away and with the third the remaining 9 are away. They need 3 guided tours; thus 90 Euro; and then that must be split; otherwise the ones would be disadvantaged that are in the smaller group; (…)

Reconstructed ways of enabling students to participate in oral explanations

Four ways of enabling students to participate in oral explanations can be observed in the reported small explorative case study. The numbers refer to the lines in the above printed transcript.

- In nearly all sequences, students utter that they do not understand parts of the mathematical discussion (see transcript #16/17, #20). The teacher *makes use of these demands of explanations and asks the class to explain in order to help their classmates understand* (#18, #21). This means in particular that the teacher is not explaining himself and also is not the receiver of the explanation.
- A second way of enabling students to participate is by *calling on several students to explain the same matter*. In the sequence "per person", three children (Uwe, Malte, and Dilay) explain how to cope with the guided tour. Like in #21, the teacher often calls on several students to give their explanations one after the other without teacher's evaluations in-between. This is not only a way to give more students the possibility to actively explain. It is also a way of using the variety of explanations in order to match the probably different needs of different listening students.
- A third way of enabling students to participate is by *giving face-saving evaluations* of incorrect or incomplete utterances (#11). By this means students feel free to contribute even if they are not completely confident about their contribution (in linguistic or mathematical issues) and hence more pupils get involved. As will be discussed later on, these face-saving evaluations contrariwise also restrain students' learning opportunities.
- A fourth way of enabling participation is to *make the epistemic expectations explicit*. For the kind of sequences analyzed in this case study this means to make explicit that the calculation should not be explained by a general procedure or conventional rules but by referring to concepts, semiotic representations, models or propositions (only very implicit in the sequence "per person"). This allows all students to participate and not only those who understand the mostly implicitly established practices of explaining.

Reconstructed ways of supporting students during an explanation

Only few short supports on lexical or syntactical levels can be observed. But deeper analysis reveals five subtle ways of epistemic and discursive support:

- One way of support can be observed in nearly every sequence of this case study: When asking the class for an explanation, the teacher *declares the calculation or its result as valid*, so that its validity needs not be argued (#15/18 by writing on the blackboard). This supports students since the case of falsifying the calculation is already excluded.
- In another sequence (not printed here), another subtle way of supporting children in explaining can be observed. The teacher starts with the question why multiplication is the right operation for a calculation. After two girls' explanations seem not to meet the teacher's expectations, he poses the question again but this time he asks why division would be the wrong operation. By *shifting from explaining why something is right to why something is wrong* he makes the explaining task easier for the students.
- A third way of support can be observed in the sequence "per person". After the first incomplete explanation of Uwe (#6/8), the teacher *splits the larger explaining task in smaller pieces* (#11, 13, 18) and thus helps Malte to structure his explanation.
- A fourth way of supporting students during explaining can be observed several times. The teacher acts as a *model for explaining, building upon students' attempts to explain and developing them further* (#24-27). By still acknowledging the students' agency of the explanation, the teacher shows the potential of the students' explanations and how they could be developed.
- Finally, a central way of enabling students to participate and supporting them is to *establish a consistent practice of explaining*, which occurs frequently in a classroom microculture. If for example the practice of explaining a calculation by referring to a conceptual epistemic field reappears several times, the underlying expectations become accessible and reliable for students, and the recurrent character of a practice provides opportunities to practice.

Reconstructed ways of fostering students in order to improve their explaining skills

Since the teacher, Mr. Schrödinger, neither explicitly evaluates the students' ways of explaining nor gives a single student the possibility to explain again after receiving support (one exception in the sequence "multiplication makes smaller"), no ways of fostering students were reconstructed in the six analyzed sequences. Although the teacher is sensitive to language, he does not engage in directly improving students' ways of explaining.

Even in the case of the sequence "multiplication makes smaller" (see below), the teacher's moves are only supporting the student Thasin to solve the current explaining task, but do not aim at fostering his competency in the long run:

Thasin expresses his discomfort with the multiplication $19.8 \cdot 0.708 = 14.0184$ written on the blackboard since the result is smaller than the factor 19. After some other students, Thasin gives an explanation himself.

...		
19	Thasin	Well, zero times nineteen equals zero, but we have a point here and that makes the zero bigger and after it there is also something written. And zero is always that it gets smaller and because it's not times one but less it is smaller than nineteen.
20	class	I didn't understand anything.
21	tea	Try it once more. But one moment. Before Thasin starts the explanation once more I'm putting this here *((changes the rough calculation at the blackboard to* $19 \cdot 0 = 0$ *and* $19 \cdot 1 = 19$*))*. Maybe you can use this Thasin.
22	Thasin	Okay, nineteen times zero equals zero and nineteen times one equals one. And here we got zero point seven hundred and eight. This is located um it's not even times one but also not times zero. That's why it must be located between the nineteen and the zero. It's smaller than nineteen but bigger than zero that's roughly.
23	class	I understand.
24	tea	yes
…		
40	tea	Exactly. I, well I clearly have to say, I couldn't have expressed that better than Thasin and Büsra did. The idea nineteen times zero is zero and nineteen times one is nineteen and with zero point seven you're in between and therefore also the result is in between is absolutely great and was expressed absolutely great.
…		

In this sequence, Thasin receives a second chance in order to improve his explanation (#21). The teacher supports him in making his explanations more understandable for the class by changing the rough calculation on the blackboard. Afterwards Thasin is actually able to structure his explanations more clearly and to make his implication more accessible for his classmates (#22). But the teacher's move only helps Thasin to improve his explanation in this context since the support is tied to the concrete task. Furthermore, the teacher evaluates Thasin's explanation positively in matters of the mathematical idea and of the formulation. Nevertheless, the teacher does not explicate why this explanation was 'absolutely great' (#40): He values the mathematical idea and recapitulates it, but he does not broach the issue of what makes the formulation of the explanation that good. Therefore, Thasin probably cannot profit from this sequence in terms of enhancing his explaining skills.

The short excerpt from "multiplication makes smaller" illustrates on the one hand how teachers can support students in challenging explanations that are important for the mathematical learning of the whole class. On the other hand it shows how learning opportunities for oral explaining can stay unused.

DISCUSSION AND OUTLOOK

The small explorative case study shows several ways of enabling participation and supporting children in oral explanations. Especially compared to other observed classrooms, Mr. Schrödinger has specific skills in including a lot of students in whole class explanations: In his classroom comparatively many students are involved with comparatively long oral explanations (Erath, in prep.; Erath et al., in prep). That means in particular that students have a lot of opportunities to practice mathematical explaining.

Furthermore, it becomes apparent that enhancing participation is more than giving students space to explain. Giving face-saving evaluations and making epistemic expectations explicit are equally important to help students to participate. But the presented case study also reveals a dilemma since some of the ways of enabling participation on the other hand may constrain learning opportunities for oral explaining. For example Uwe (in the sequence “per person”) does not get a chance of improving his explanation because the teacher directly calls on the next student Malte. In the following interaction it is Malte (and not Uwe) who receives support by the teacher by splitting the explaining task in smaller pieces. In this way another student gets the opportunity to actively take part in the explanation but simultaneously Uwe does not obtain an individualized learning opportunity. But also face-saving evaluations can be problematic. Since students do not get an explicit feedback, they may miss learning opportunities or, from the other perspective, the teacher may miss opportunities to foster students. This is reinforced by the teacher’s habit of giving summarizing evaluations after several students explained.

This potentially problematic implicitness cannot only be observed on the level of enabling participation. Establishing a consistent practice of explaining is a central way of supporting students, but deeper analysis of the corresponding processes shows that these mainly take course in an implicit way (Erath, in prep). That is on the one hand, students can learn to participate in the established practices of explaining since they are recurrently processed and mostly tied to a certain classroom situation. But on the other hand they need to be able to interpret the implicit processes and realize the underlying patterns of practices in order to take part in explanations. Altogether the implicitness in handling explaining as a learning goal can be very challenging for students and studies show that not all students can master this sufficiently (e.g. Gellert & Hümmer, 2008). This emphasizes the importance of another way of supporting students during explanations: making epistemic expectations explicit.

An important result of the presented case study is the observation of support on an epistemic and discursive level instead of support on lexical or syntactical levels. This is remarkable since a lot of teachers focus on the latter. Also research in mathematics education (especially in the context of second language learners) often focuses on these levels of language: Many empirical studies and approaches for fostering academic language in mathematics mainly refer to knowledge of vocabulary and/or grammar in connection to reading competence (e.g. DfEE, 2000; Paetsch, Felbrich, & Stanat, 2015). But like for example Moschkovich (2015) and Barwell (2012) more and more researchers in mathematics education are working on the role of discourse in mathematics education. The example of Mr. Schrödinger’s classroom shows that support on epistemic and discursive levels is successful in helping students to explain in an understandable and meaningful way. Therefore, the teacher fulfills Moschkovich’s demand of enabling all students to participate in mathematically meaningful discussions.

Mr. Schrödinger enables participation and supports the students during the explanation sequences in several ways, but none of them serves to improve the explanations of an individual student from a long-term perspective. In the six analyzed sequences, explaining serves as a medium for learning mathematics. It is used to reveal the connections between conceptual and procedural knowledge and therefore for building a meaningful understanding of mathematics. But explaining is not observed as (implicit) learning goal. Of course, it is possible that the teacher treats explaining as an explicit learning goal in lessons that are not part of the videodata. But broader research on this classroom indicates that explaining remains on the level of a learning medium (Erath, in prep.).

This result leads to the question how explaining and discourse in general can become more explicit learning goals in mathematics education and how ways of fostering oral explanations could be designed. Furthermore, the question in what extend students with low discursive competencies are disadvantaged during the process of learning mathematics comes to the fore. Therefore, further interdisciplinary research with partners from linguistics and language acquisition is needed.

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REFERENCES

Barwell, R. (2012). Discursive Demands and Equity in Second Language Mathematics Classrooms. In B. Herbel-Eisenmann, J. Choppin, D. Wagner, & D. Pimm (Eds.), Equity in Discourse for Mathematics Education (pp. 147-163). Dordrecht: Springer.

Erath, K. & Prediger, S. (2015, in press). Diverse Epistemic Participation Profiles in socially established explaining practices. To appear in K. Krainer & N. Vondrová (Hrsg), Proceedings of CERME 8, Prag: Charles University / ERME.

Erath, K. (in prep.). Mathematisch diskursive Praktiken des Erklärens in unterschiedlichen Mikrokulturen. Rekonstruktive Analysen von Unterrichtsgesprächen. PhD-Thesis. TU Dortmund.

Erath, K., Prediger, S., Heller, V., & Quasthoff, U. (in prep.). Learning to explain or explaining to learn? Discourse competences as an inmportant facet of academic language proficiency.

DfEE (2000). The National Numeracy Strategy: Mathematical Vocabulary. London: Department for Education and Employment. http://www.belb.org.uk/Downloads/num_mathematics_vocabulary.pdf (Last retrieved January 23, 2016).

Gellert, U. & Hümmer, A.-M. (2008). Soziale Konstruktion von Leistung im Unterricht. Zeitschrift für Erziehungswissenschaft, 11 (2), 288–311.

Heller, V., & Morek, M. (2015, in press). Unterrichtsgespräche als Erwerbskontext. Kommunikative Gelegenheiten für bildungssprachliche Praktiken erkennen und nutzen. Themenheft im Leseforum.ch(3).

Hiebert, J., & Lefevre, P. (1986). Conceptual and procedural knowledge. An introductory analysis. In J. Hiebert (Ed.), Conceptual and procedural knowledge. The case of mathematics (pp. 1–27). Hillsdale, NJ: Lawrence Erlbaum.

Lampert, M., & Cobb, P. (2003). Communication and learning in the mathematics classroom. In J. Kilpatrick & D. Shifter (Eds.), Research companion to the NCTM Standards (pp. 237–249). Reston: National Council of Teachers of Mathematics.

Morek, M.; Heller, V. & Quasthoff, U. (in press). Argumentieren und Erklären. Konzepte, Modellierungen und empirische Befunde im Rahmen der linguistischen Erwerbs- und Unterrichtsforschung. In E.L. Wyss (Hrsg.), Erklären und Argumentieren. Konzepte und Modellierungen in der Angewandten Linguistik. Tübingen: Stauffenburg.

Moschkovich, J. N. (2015, in press). Academic literacy in mathematics for English Learners. To appear in Journal of Mathematical Behaviour, http://dx.doi.org/10.1016/j.jmathb.2015.01.005

Paetsch, J., Felbrich, A., & Stanat, P. (2015). Der Zusammenhang von sprachlichen und ma¬thematischen Kompetenzen bei Kindern mit Deutsch als Zweitsprache. Zeitschrift für Pädagogische Psychologie, 29(1), 19-29.

Prediger, S., & Erath, K. (2014). Content or interaction or both? Synthesizing two German traditions in a video study on learning to explain. Eurasia Journal of Math., Science & Techn. Ed., 10(4), 313-327.

Smit, J., van Eerde, H. A. A., & Bakker, A. (2013). A conceptualisation of whole-class scaffolding. British Educational Research Journal 39(5), 817-834.