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Implicit and explicit processes of establishing explaining practices – Ambivalent learning opportunities in classroom discourse

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Participation in mathematical practices is widely accepted as important for students' meaningful learning of mathematics. But how do students learn to adequately participate in these practices? This paper addresses the question for the specific case of oral explaining practices in whole class discussions. The study is theoretically based on merging an interactionist and an epistemological perspective to describe explaining practices as interactive processes in a classroom microculture while simultaneously keeping in mind the development of the broached mathematical content. The identified implicit and explicit processes of establishing explaining practices are exemplified and discussed with respect to ambivalences in the differing learning opportunities they offer.

Keywords: Explaining practices, student participation, discourse, interaction, implicitness.

Introduction

This study is based on the assumption that students' learning is inseparably linked to participation in classroom interaction, which is mainly based on verbal communication. Therefore, learning of mathematics is conceptualized as “a process of enculturation into mathematical practices, including discursive practices (e.g., ways of explaining, proving, or defining mathematical concepts)” (Barwell, 2014, p. 332). In this study, the discursive practice of explaining in whole class discussions is further investigated. Erath, Prediger, Heller, and Quasthoff (submitted) show that explaining is the most frequent discursive practice in German grade 5 mathematics classrooms. Furthermore, explaining has an important role for the meaningful learning of mathematics since it serves to communicate about more isolated pieces of knowledge, including talking about meanings and connections (Prediger & Erath, 2014). But how do students learn to participate in explaining practices and the corresponding epistemic processes? This question is investigated in this paper on the level of the interactive processes of establishing explaining practices in four microcultures.

Theoretical background: Explaining as practices of navigating through different epistemic fields

Following Interactional Discourse Analysis, explaining is understood as multi-turn units which are interactively co-constructed, contextualized and serve to convey or construct knowledge (Erath et al., submitted). This definition is extended and intertwined with an interactionist and an epistemological perspective from mathematics education: From an *interactionist perspective*, explaining can be conceptualized as a mathematical practice (Cobb, Stephan, McClain, & Gravemeijer, 2001) that is interactively established in a classroom microculture and that allows talking about collective mathematical development. Here, this concept is used descriptively to talk about identified ways of collective explaining processes in whole class discussions that are interactively established by students and the teacher. But not every explanation constitutes an own practice. To clarify this point, the notion of mathematical practices is enriched by the following definition from general educational science: “Practices are [...] understood as rule-governed, typecasted, and routinely recurring

activities” (Kolbe, Reh, Fritzsche, Idel, & Rabenstein, 2008, p. 131; translated from German by the author). Therefore, mathematical explaining practices are conceptualized as *recurrent* ways of explaining that are treated as matching the classroom microculture from the participants’ perspective.

The *epistemic matrix* was derived from research in mathematics education from an *epistemological perspective* (Prediger et al. 2014) and is used to further specify the notion of ‘recurrent ways of explaining’. Different possible objects of explanations in mathematics are systematized in the lines of this matrix (not readable in Figure 1 that focusses on the depicted pathways), called *logical levels* (from top to bottom): Concepts, propositions, representations, and models (conceptual logical levels) and conventional rules, procedures, and concrete solutions (procedural logical levels). Each of these mathematical aspects can be explained by different means that are distinguished in the columns of the matrix (Prediger & Erath, 2014), called epistemic modes (from left to right): Labeling & naming, explicit formulation, exemplification, meaning & connection, and purpose & evaluation.

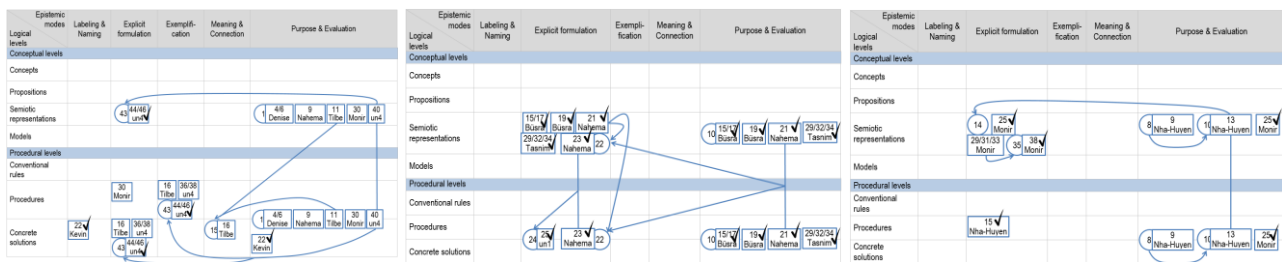


Figure 1: Three explaining pathways contributing to the practice of explaining ‘good’ representations

On the one hand, the epistemic matrix is used to characterize the utterances of students and teachers in explanations by analyzing which cells (called *epistemic fields*) of the matrix they address. On the other hand, the matrix is used to depict the *explaining pathways* that are interactively established by mapping these characterizations of utterances in the matrix (see Figure 1): Students’ utterances are depicted as rectangles (including turn number and name), the teacher’s utterances as circles with turn numbers. These pathways give access to the underlying mathematical structure of explaining sequences, which are especially characterized by the teacher’s navigations through different epistemic fields (indicated by arrows in the pathways). Therefore, the matrix is used as tool of analysis and at the same time the associated language of ‘explaining pathways’ serves to specify the definition of explaining practices: Altogether, explaining in mathematics classrooms is conceptualized as practices of navigating through different epistemic fields, which are identified by building categories of pathways with similar structures (Erath, 2017). Hence, different practices are constituted by different defining patterns of their pathways describing the ‘recurrent ways of explaining’. For example, all three pathways in Figure 1 have entries in the lines of “representations”, “procedures” and “concrete solutions” in common and after working in the column of “purpose & evaluation” (more on the right) the teacher navigates towards the column of “explicit formulation” (more on the left). This recurring pattern defines the practice of explaining ‘good’ representations in one classroom: “navigating from the evaluation of a student’s concrete solution and suggestions for improvement to deriving more general hints for drawing and characteristics of good representations”.

But how do students learn to adequately participate in these interactively established explaining practices? Studies on the establishment of related norms in mathematics education (e.g. Yackel & Cobb, 1996) and discourse analysis (Heller, 2015) identify implicit and explicit processes as oppor-

tunities for students learning how to explain in their classroom. This work is extended to the processes of establishing explaining practices in this paper.

Methodology of the study

Larger data corpus. In the larger project INTERPASS, video data was gathered in 10 x 12 mathematics and language lessons (each 45-60 min.) in five different grade 5 classes (age 10-11 years) in an urban area of Germany. Eight lessons were observed in the beginning of the school year directly after the transition from primary school since it could be expected that processes of establishing practices are more explicit in this time of getting to know each other. Further four lessons each were gathered in the middle of the school year in order to get a long-term impression.

Sampling for the case study of this paper. The presented study builds on data of four mathematics classrooms chosen due to the following different characteristics in order to observe a broad range of interactions (Erath, 2017): Two higher tracked secondary schools (German: “Gymnasium”) and two normal secondary schools (German: “Gesamtschule”) and within each of these subgroups one classroom with students from a privileged and one with students from an underprivileged quarter.

Data analysis. This paper is based on analyses done for the PhD thesis “Mathematical discursive practices of explaining in different classroom microcultures” (Erath, 2017) enrooted in the larger project INTERPASS. In this context, all explaining sequences in whole class discussions were transcribed and analyzed by means of the epistemic matrix resulting in explaining pathways for each sequence. In a second step, explaining practices were identified in each classroom by developing categories of pathways with similar structures. In this way, three to five different explaining practices were explored in each of the four classrooms. In order to answer the question “How do students learn to adequately participate in the explaining practices of their classroom?” the interactive processes of establishing practices were further investigated. More precisely, it was explored if these processes were explicit or implicit and which turn teachers use in order to express their expectations and if this makes any difference for students learning opportunities.

All presented transcripts were translated from German and simplified (capital letters indicate stressed words, round brackets indicate phrases difficult to understand in the video data).

Empirical results: Processes of establishing explaining practices

The investigation of processes of establishing explaining practices in four German grade 5 classrooms (Erath, 2017) shows that there are some explicit but primarily implicit processes that contribute to the establishment of explaining practices. Furthermore, it comes to the fore that teachers (implicitly or explicitly) explicate their expectations in the turn of demanding an explanation as well as in the turn of responding to a student’s utterance.

Explicit processes

Out of 16 identified explaining practices, only the practice of “explaining a concrete solution by means of a conventional rule” in Mr. Maler’s classroom is recurrently established in an *explicit* way. The following transcript from the sequence “rounding on tens” (see Prediger & Erath, 2014 for a longer extract of the sequence) exemplifies how the teacher explicates his expectations for a ‘good’ explanation in his response to Kosta’s explanation why 63 can be rounded on 60:

- 8 Kostas: °hhh [*articulated clearing his throat*] Well, if you are rounding DOWN the sixty-three on TENS; then it comes, it gets, there must be ALWAYS a zero at the end, it MUST be,
- 9 Teacher: [hm_hm]
- 10 Kostas: [when you are rounding.]
- 11 Teacher: On TENS yes.
- 12 Kostas: And then there, if you take AWAY the three and shift the ZERO to it. So, you could DO that, but actually it's WRONG. You just have to round down and nea.. nearest number with a ZERO you have to write there.
- ...
- 20 Teacher: [...] and you already implied WHY; but does any of you know a RULE, HOW one has to proceed here, and when one here, when the ten stays the SAME? In this case, and the place BEHIND, which is rounded, goes to ZERO? Ha; [4.5 sec. break] Katja.
- 21 Katja: With zero one two three FOUR you are rounding down and with five six seven eight NINE you are rounding (up). [3.5 sec. break]
- 22 Teacher: Did EVERYBODY understand that?
- 23 Class: YES [*affirms in choir*]

Kostas explains his solution by referring to the meaning related model of distance and closeness on the number line. This is implicitly rejected as a matching explanation by the teacher in #20, immediately followed by questioning the class about a rule that could be applied to explain the solution. In this way, Mr. Maler explicates his idea of a 'good' explanation of a concrete solution, which is underlined by his reaction to Katja's formulation of the corresponding rule. This sequence is an example of explicating expectations in responding to a student's explanation by navigating to the epistemic field (explicit formulation of a conventional rule) that would match for an explanation from the teacher's perspective and directly demanding an answer in this epistemic field. Another conceivable possibility would be that the teacher explicitly talks about which mathematical aspect of an explanation he values or which part did not match from his perspective.

These kinds of explicit processes can also be observed in Mr. Maler's demands for explaining a solution. The following extract from "rounding on thousands" in the context of a homework on rounding the length of rivers illustrates the case of explicating expectations in the turn of asking for an explanation by pointing to the expected epistemic field (explicit formulation of a conventional rule):

- 6 Tabea: SIX thousand
- 7 Teacher: GOOD; but now my QUESTION is, HOW did you arrive at this six thousand? Since we also want the RULE
- 8 Tabea: Because from e:r,
- 9 Teacher: to be CLEAR
- 10 Tabea: Well up to five, well up to four, you have to round DOWN, and from five six seven eight nine you have to round UP.
- 11 Teacher: EXACTLY. [...]

After naming the right number (#6), Tabea is asked by the teacher in #7 to explain her solution. In this turn of demanding an explanation he directly states that she should refer to the conventional rule (shortly interrupted by Tabea): "HOW did you arrive at this six thousand? Since we also want

the RULE [...] to be CLEAR” and in this way explicitly points to the expected epistemic field. Tabea follows this navigation (#10), which is explicitly evaluated positive by Mr. Maler in #11.

In both ways, the teacher explicates his expectations and reveals the recurring, typical structure of explaining a concrete solution by means of stating the related conventional rule. That is, this structure is made accessible to all learners and not only to those who can interpret the implicit processes of establishment (see below). Hence, the teacher’s explication of expectations in the turns of demanding for and responding to an explanation are major learning opportunities for explaining a concrete solution adequately in this classroom (this must not hold for other classrooms since every microculture establishes different practices). Especially the way of explicating in the demand for an explanation seems to be important: This allows all children to contribute in the subsequent explanation even though they might not yet recognize the recurrent pattern of the underlying practice.

Implicit processes

Explicit establishments (see above) have only been found in rare cases in the data corpus. Instead, processes take course implicitly. Three different ways of *implicit* processes contributing to establishing explaining practices were identified and are exemplified in the following: (1) marking match or mismatch in responding to a student’s explanation without giving reasons for the evaluation, (2) picking up only particular aspects of a student’s explanation without explication, and (3) navigating recurrently to specific epistemic fields without revealing the underlying (intended) pathway.

An example for evaluating a student’s explanation without further comments is the sequence “distinguish lists” from Mrs. Bosch’s classroom. During revision at the beginning of the lesson, students are asked to distinguish the concepts of tally sheets and frequency tables.

- 12 Teacher: [...] Now, WHAT was tally sheet, WHAT was frequency table, this PART, Barbara,
- 13 Barbara: Tally sheet is where you did strikes; and frequency table is er [4.0 sec. break] er-
- 14 Teacher: Can you HELP Maria?
- 15 Maria: YES, when you did it all count up and then wrote it DOWN with numbers
- 16 Teacher: EXACTLY. Well CAUGHT. [...]

Mrs. Bosch marks Maria’s explanation explicitly as matching (#16) but does not reveal the underlying pathway in her response: The analysis of several sequences on explaining concepts in this classroom unfolds that in this microculture a concept is adequately explained by means of addressing an epistemic field on the level of procedures, which means formulating an instruction for generating a representation of the concept. Therefore, the sequence is an example of an implicit process that contributes to the establishment of an explaining practice by marking an explanation as matching or mismatching without commenting on the reasons for the evaluation.

The second kind of implicit processes (picking up only particular aspects of a student’s explanation in a response without explication) is concretized by the sequence “function of diagrams” from Mr. Schroedinger’s classroom in the context of talking about different ways of presenting data.

- 1 Teacher: [...] WHY they’re doing quite frequently in printed media but also um on TV in the news, um why they’re not giving a LIST like that [...]

- 2 Nikolas: um because maybe because this CATCHES one's eye much faster and um well that you can SEE this faster; so that something is BIGGER; because this is also bigger from its SIZE. So it's MORE because it's BIGGER from its size.
- 3 Teacher: [nods] [Markus]
- 4 Marcus: [Because you] can CATCH it very fast. For example um now up RIGHT I think there are such PERCENTAGES; because (that they) CATCH that well it's actually even BETTER than this; (also how many) PEOPLE;
- 5 Teacher: hm_[hm]
- 6 Marcus: [How] many SIBLINGS they have, because then in parts they would maybe have to always go THROUGH our classroom that small.
- ...
- 9 Teacher: THIS exactly meets the point, these two utterances. THEREFORE you normally do it in the form of such diagrams, because of the clarity actually [...]

In his evaluation in #9, the teacher explicitly marks that the students' answers match but in his subsequent summary, only specific aspects are picked up: The teacher takes on the aspects related to functionality but he does not refer to the further issues of meaning (#2, "it's MORE because it's BIGGER") or examples (#4/6, number of siblings) addressed by the students. This selection is in line with the practice of explaining that is established during several sequences: In Mr. Schroedinger's classroom, concepts are adequately explained by referring to purposes and functionality.

The third way of implicit processes contributing to establishing a practice is the teacher's repeated steering to specific epistemic fields without revealing the underlying (intended) pathway. This directly refers to the definition of explaining practices that forms the basis of this study. Figure 1 shows three pathways of sequences that show the same regularities. These kind of pathways are identified five times in Mr. Schroedinger's classroom in the context of explaining how 'good' representations are designed. But, as with the two ways illustrated before, the underlying pathways are not revealed. The following extract from the sequence "lists of pets" exemplifies the navigation from evaluating a concrete solution to formulating hints for generating 'good' representations.

- 1 Teacher: What would you SAY which ADVANTAGES, DISADVANTAGES [*break 1.3 sec*] have these particular ways of writing it down; [...]
- 34 Büsra: Well, in my POINT of view number two is BEST [*break 1.7 sec.*]
- 35 Teacher: WHY; [*break 1.2 sec.*]
- 36 Büsra: Yes because it doesn't that much TIME and em like Monir-Zohir already SAID em it only takes you like two MINUTES or so-
- 37 Teacher: hm_HM, [*break 1.3 sec.*] But with number two TOTALLY obvious- something is MISSING in order to make it as clearly arranged as POSSIBLE [...] WHAT is missing TOTALLY obvious with number two so you can SAY yes THIS makes somehow sense- this there you need LITTLE time- this is SOMEWHAT clearly arranged
- ...
- 40 Uwe: the NUMBERS; [*break 1.7 sec.*]
- 41 Teacher: SAY again- WHY does it make sense to write numbers behind it?
- 42 Uwe: So that you don't always have to count THROUGH;

43 Teacher: [writes on the transparency] EXACTLY; [...]

Mr. Schroedinger initiates (#1) the evaluation of the representations and after some students stated pros and cons for the different representation, he navigates to formulating suggestions for improving the lists (#37), which helps clarifying how good lists should be designed. By repeatedly starting from a student's concrete solution and navigating from its evaluation and suggestions for improvement to deducing more general hints for drawing and characteristics of good representations this explaining practice is established across several sequences.

Although the three presented ways of establishing explaining practices must be characterized as implicit processes, they serve as opportunities to learn how to participate adequately in whole class explanations, at least for some learners. But the examples also show how challenging it is for other students to interpret these implicit processes (see e.g. Gellert, 2009, for further discussion of divergent learning opportunities related to implicitness). In the cases of marking matches and mismatches or picking up particular aspects without further comments, it might be challenging for students to follow since they must relate the teacher's evaluation to a classmate's utterance that is not present any more. The third way (recurrent teacher's navigations) allows all students to contribute in the explanations as long as the teacher explicitly demands for the shifts of epistemic fields. However, it probably takes students several sequences of one practice to recognize that there is a pattern and that knowing "how explaining works" is important for adequately taking part in whole class discussions.

Conclusion and discussion

The distinct dominance of implicit processes found in the qualitative analysis of the video data corpus is in line with research that identifies criteria of "successful participation" and "expected student contributions" (Gellert, 2009, p. 131, translated from German by the author) as often staying implicit. The presented study deepens these findings for explaining practices. Furthermore, the epistemic matrix offers a possibility to talk about mathematical aspects of 'good' explanations and to make the hidden regularities visible and discussable by means of the pathways. The dominance of implicit processes also suits the observation that explaining (as well as oral communication in general) is not treated as an explicit *learning goal* by the teacher (Erath, 2017). Instead, explaining serves as *learning medium* that is used without talking about adequate participation beyond general social behavior, i.e. the mathematical aspects of 'good' explanations. Moreover, it becomes apparent that learning how to adequately participate in whole class explanations is a learning process (across several sequences and lessons) and hence especially not a feature that students bring to the classroom but a competence that can be acquired in the interaction of collective explanations guided by the teacher.

The explicit and implicit processes of establishing explaining practices relate to different learning opportunities for students as explicated above: More explicit processes are eligible since they reveal the underlying patterns of the pathways and provide more students access to this mathematical aspects of participation, not only those who are able to also interpret the implicit processes. However, this does not imply a call for direct instruction: Talking about language on meta-level while simultaneously talking about mathematical content may ask too much especially from weaker students. Instead, it is about making the criteria for matching and mismatching utterances in relation to a practice accessible in responses to explanations or in the turn of demanding for explanations. Therefore, teachers need to be sensitized for the role of oral explaining as a learning goal in order to be able

to deliberately initiate particular practices. But as a first step, research in mathematics education should further specify which explaining practices are reasonable (also related to general discourse acquisition) or rather necessary in which grade in order to help teachers to enable even more students to actively participate in oral explanations and the corresponding epistemic processes.

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