DEVELOPMENT OF MATHEMATICS TEACHERS' PROFICIENCY IN DISCUSSION ORCHESTRATION

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Abstract:

This paper describes a study in progress that examines development of the teacher's proficiency in managing a whole-class discussion in the context of her experience of teaching students in an inquiry-based learning environment. Discussion segments of two lessons by one teacher with the same class, which were were condacted a year and a half apart, are analyzed. We suggest elements of a structure for discussion orchestration. Using these elements for the micro-analysis of the lesson segments we demonstrate a possible evolution of teacher proficiency.

BACKGROUND

The study presented in this paper focuses on the development of the teacher's proficiency in managing a whole-class mathematics discussion. This type of teachers' endowment is central for many reform-oriented curricula that establish, strengthen and broaden conjecturing, exploration, and investigation procedures in the mathematics classroom (e.g., Ball, 1992; Lampert, 1990; Lampert, 2001; Schifter, 1996; Yerushalmy, Chazan & Gordon, 1990). Teachers are no longer considered the central source of mathematical truth, but rather act to support students by creating problem-solving situations, to acknowledge the value of students' ideas and to respond to them. As the nature of the mathematical task moves towards exploration, the structure of a whole-class discussion changes as well.

In such a clussroom students and their teacher share their roles in the classroom, i.e., the teachers and the students listen to each other, reflect on and clarify others ideas, perform representation translations, and provide explanations (Lampert, 2001; Forman & Ansell, 2001). We believe in the possibility of (almost) symmetrical roles of teachers and students in classroom discussion, however we assume that sharing roles between a teacher and the students depends heavily on the teacher's proficiency. We assume that a teacher without an experience in orchestrating a classroom discussion would be more dominant and less open to students' needs. This study stems from the standpoint that teaching provides many important opportunities for professional development (e.g., Ma, 1999) and examines how discussion orchestration changes through teaching experience.

In their analysis of the discussion orchestration Forman & Ansell (2001) demonstrated that I-R-E (initiation-response-evaluation) social participation structure of the traditional classroom suggested in the 1970s (e.g., Mehan, 1979) does not reflect the structure of discussion orchestration. A discussion can contain several different patterns of interaction, so that there may be several possibilities with respect to IRE structure (e.g., it

may not appear at all, or only sometimes). Variations in discussion structure are closely connected to the variations in roles of students and teachers in such a discussion. In inquiry-based discussions there are shifts toward teachers' reflectivity and flexibility. In this study we try to detail these shifts in terms of teacher's discussion actions.

Research on mathematics teachers' education demonstrates the importance of flexibility, deepness and connectedness of teachers' mathematical knowledge (e.g., Ball, 1992; Lampert, 1990; Schifter, 1996). Ball (1992) establishes teacher knowledge about the nature and discourse of mathematics as essential part of teachers subject-matter understanding. Jaworski (1992) defines the essence of mathematics teaching as being placed in three domains: the management-of-learning, sensitivity-to-students, and mathematical-challenge. This study tries to analyze development of teachers' proficiency of managing the whole-class student-sensitive discussion through presenting students with challenging mathematical questions.

THE PURPOSE AND THE QUESTIONS

The purpose of the current study is ***to characterize teacher's actions*** in the inquiry-based classroom discussion and ***to analyze changes in the teacher's actions*** over time in order to identify what kinds of teacher behavior makes discussion more effective, reflective and flexible. In this paper we focus on two questions:
(1) What are the main types of teacher actions in the inquiry-based classroom discussion?
(2) How do these actions change in the course of teaching practice?

METHOD

The teacher: Shelly -- the first author of this paper -- was a beginning teacher, having graduated with her B.Ed. three years before the experiment in her classroom started. During first three years of her teaching career she took part in a professional development program for elementary school mathematics teachers. The course was focused on inquiry-based learning of mathematics. During the second and the third years of the professional development program she joined a development team that specialized in materials for an inquiry-based mathematics classroom (Fridlander, 1997; Fridlander & Rota, 1996). At the end of the professional development program, Shelly started experimental implementation of the new learning materials. Our study considers Shelly's teaching experiment (Cobb, Wood & Yackel, 1990) during two years and the development of Shelly's proficiency through teaching.

The data: Overall about 20 of Shelly's lessons were videotaped during the two years of the experiment for the purpose of the formative evaluation of the teaching materials. Thus at that time she was not aware of the possibility of using these data for the purposes of the current study. For the purposes of this study, three of 20 lessons with the same group of students and very similar in their structure were chosen. This paper presents analysis of teachers discussion actions during these three lessons and analyzes changes in the teacher's actions using 10-minutes segments from two of these three lessons, which were 1.5 years apart. The first lesson took place when the students were in the middle of the 2nd grade (January, 1993), the

second lesson took place when the students were at the end of the 3rd grade (May, 1994).

Lesson structure: As noted above, the two lessons have very similar structure including three main stages: Introduction, Inquiry, Summary-discussion. In the very short introduction stage Shelly presented students with the problem. During the inquiry stage the students worked in small groups and Shelly helped them to progress in their investigation when the help was needed. The last stage of the lesson, which is under investigation in this paper, is the whole-class summary-discussion. During this stage the students from the small groups shared results of their investigations with the whole class, they made conjectures, discussed them, compared different solutions of the problem and tried to come to a conclusion. The teachers' role in this setting was helping students make progress in their presentations, generalize the results and finish the lesson with shared mathematical meaning.Mathematical tasks for both of the lessons included series of questions that were under students' investigation. Below we present mathematical tasks that were at the focus of the discussion in the segments of the lessons considered in this paper.

Task for the segment from the first lesson: In this task (from Dice activity: Fridlander & Rota, 1996) the children investigated the relationship between a graph and the common property of the points in the graph. In this paper we refer to the part of the Discussion that was dedicated to the following questions (Figure 1).

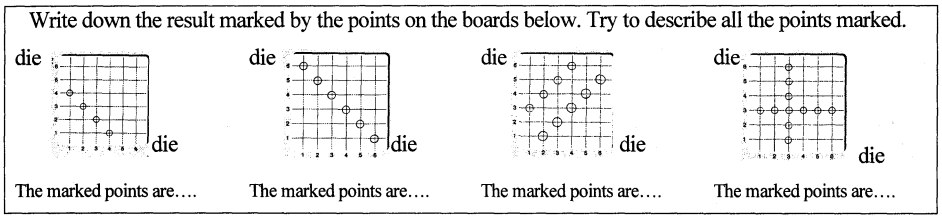


Figure 1: Task for the segment from the first lesson

Task for the segment from the second lesson: In this task the children dealt with an unknown number of matches that satisfy a given condition (from Matches activity: Fridlander & Rota, 1996, see Figure 2).

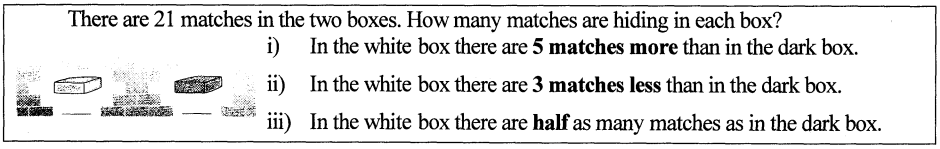


Fig 2: Task for lesson 2

DATA ANALYSIS AND RESULTS

We would like to be precise in the description of Shelly's flexibility. Thus, first we present main types of the teacher's actions in her classroom and then analyze the changes that were found in Shelly's discussion orchestration.

Main types of teacher's discussion actions: During *whole-class discussion* Shelly performed different actions that composed her discussion orchestration. While students' learning activities were mainly focused on solving a mathematical problem and were aimed at constructing students' personal mathematical meaning, Shelly's activity was mainly focused on solving teaching problems and on supporting students' construction of the mathematical meaning. Based on Forman & Ansell's (2001) statement that both the teachers and the students are "involved in revoicing each other and listening to, reflecting on, clarifying, expanding, translating, evaluating and integrating each other's explanations", we tried to zoom in the transcripts of the discussions and to identify precisely main teachers' and students' discussion actions. We first defined three main classes of the discussion actions: class of *Stimulating Initiation* including actions that begin discussion of a new mathematical question; class of *Stimulating Reply* including actions that stimulate continuatoin of a discussion and are connected to prior utterances; and class of *Summary Reply* including actions that finish discussion of a particular question. Second, based on our analysis of the transcripts of the three lessons, we defined possible teaching discussion actions. We (the two authors of the paper) defined these categories of actions independently, discussed the terminology and agreed about the following categories to be used in the further analysis. Note, that in this paper we present the part of the study that analyses teacher's discussion actions only.

Questioning: In this category we included utterances in which Shelly presented students with a problematic situation and invited students to find a solution to this situation. In other words, posing a problem, starting a new stage of the discussion, changing a problem under consideration were all attributed to the questioning category. A teacher may ask a question that was planned or may refer to (reflect on) a student's conjecture, statement, or difficulty. Thus, questioning category was subdivided into different sub-categories according to their purposes in the course of the discussion (e.g., Opening questions, like "Who is ready to present his solution?" Promoting questions, like "And then what did you do?" Clarification questions, like: "Why did you take [this numbers] one and two?" or "What can you tell about the points on this diagonal line?" or "Let's check whether this results is correct."). Note here that the teacher's utterance was categorized as questioning without relation to its semantic structure. Mainly questioning appeared at the two stimulating stages. Note also that in our segments "Stimulating Initiation" appeared in questionning form only.

Translating a representation: Teacher's action in which she performs symbolic or graphical representations of students' utterance, like writing and drawing on the board were considered as performing translation between representations. In our segment this category was usually accompanied by constructing a logical chain.

Constructing a logical chain: These teacher's actions include a chain of the type "*if – then*". Initially, this category was considered a complex explanation but at the later stage of the analysis complex explanations were subdivided into translating representations and constructing logical chains.

Repeating students' utterance: A teacher repeats exactly what a student said. This action was performed for different purposes, e.g., to continue discussion, to stress the student's

idea, to invite students to think about the correctness or the conjecture. Thus according to the purposes of the repetitions they were subdivided into other subcategories.

Hinting: In some situations, when Shelly felt that the discussion was stuck, she tried to help students to move forward in their reasoning mainly by means of *connections* with other similar cases in which they applied a similar problem-solving strategy or algorithm. For example: "Think how I usually write this".

Stating a fact: In this category we included teacher's statements of mathematical or metamathematical facts.

Providing feedback: Teacher's reflective evaluation of students' solutions was included in this category of teachers' actions.

Figure 3 demonstrates the coded transcript of the segment of discussion in the second lesson.

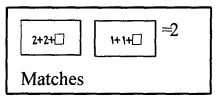
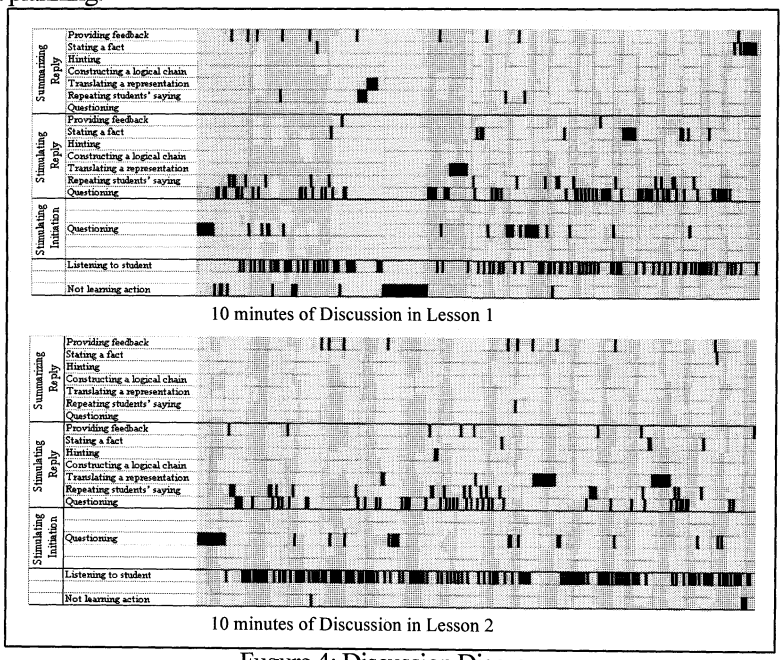
Time	Name	Utterance	Coding
0:16:05	Shelly	O.K. [Ben is raising his hand] Ben, how did you do it?"	Summary reply: *Feedback* Stimulating initiation *Questioning*
0:16:07	Ben	I took the all twenty one matches. I put two in one side and after every two in one side I put two in the ather side, two in one side and one in the ather. I did so untill I had in one box seven and in the ather fourteen.	Listenning to students
0:16:23	Shelly	Why you took two and one two and one?	Stimulating reply: *Questioning*
0:16:27	Ben	Because two divided by one equals one and half of two is one.	Listenning to students
0:16:33	Shelly	O.K. Half of two is one. Did you understand what Ben did?	Stimulating reply: *Feedback* Stimulating reply: *Repeating* Stimulating reply: *Questioning*
0:16:37	Asaf	Two divided by one equals one	Listenning to students
0:16:39	Shelly	Two divided by one equals two [Shelly is drawing on the board while she is talking to the class] What Ben said was that he took.. half of two is one, right?. So, every time he took two and put them here he put one there, add two here and one there until he had no matches.  How many did you have here? [Shelly is pointing to the writing on the board]	Stimulating reply: *Stating a fact* Stimulating reply: *Translating a representation* Stimulating reply: *Questioning*

Figure 3: Example of the coded transcript (from discussion in lesson 2)

Changes in teachers' actions over time: After defining the categories we turned back to the transcripts and coded teachers' actions in the two transcript segments (each 10 minutes long) independently (see example in Figure 3). Ninety-three percent of discussion actions (of the total number of teaching discussion actions) were coded identically by the two coders. The other seven percent were discussed in order to achieve an agreement on the coding. We applied the Shoenfeld (1985) analysis schemes to solving the teaching problems. Figure 4 presents micro time-line analysis of Shelly's discussion actions embedded in the transcripts. The scale along the horizontal axis indicates time. Ten minutes of each segment were divided into 300 units of two seconds. The labels along the vertical axis indicate different teachers actions at the different stages of the discussion.

Figure 4 provides visual support for our suggestion about development of teacher's proficiency in managing a whole-class discussion. We may see that during the second lesson Shelly was listennig to the students more while the students were more active participants of the discussion. We may see that Shelly is less active at the stage of stimulating initiation thus we may suggest that students had more possibilities to initiate discussion. We see only a few summarizing actions that Shelly performed during the second lesson discussion. The nature of the actions at this stage also changed. At the stage of summarizing reply during the first lesson Shelly repeated students' utterances, translated representations and stated facts whereas in the second lesson she mostly provided (positive) feedback to students' actions. At the stage of stimulation reply during the second lesson Shelly provided fewer hints and asked fewer questions than in the first lesson. At the same time Shelly repeated students' statements, and provided more feedback as stimulating reply. In her reflective analysis of the lessons Shelly points out that during the second lesson she felt more secure in basing the discussion on students' conjectures whereas during the first lesson she felt she needed to proceed according to her initial planning.

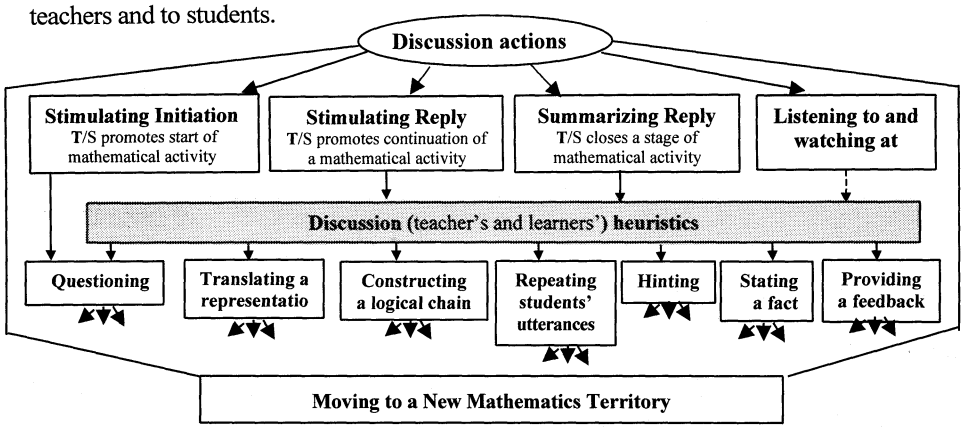


Fugure 4: Discussion Diagrams

Overall we found that Shelly was much more flexible during the second lesson; she was able to change her initial plans in terms of ideas the students presented, and was able to show more trust in her students. This changes in flesibility we describe in terms of discussion actions that were differently distributed between and within the three main classes of actions.

DISCUSSION

We defined four large categories of teachers discussion actions that we refered to as classes of actions. Two of these classes were subdivided into seven categories of teacher's actions (see Figure 5). Our categories are consistent with Lampert's (2001) latest description of management of a whole-class discussion in which she divided her lesson into episodes according to the teacher's roles in the discussion and with Forman and Ansell's (2001) social participation structure of the classroom. In terms of Lampert all these teacher's actions were aimed to lead students into new mathematics territory (see Figure 5). As noted earlier, we consider teacher's and students' roles in the inquiry based classroom to be almost symmetrical, thus in Figure 5 all the actions are attributed both to teachers and to students.



Fugure 5: Discussion actions

We provided a microanalysis of the structure of the discussions in two lessons by the same teacher with the same students one-and-a-half years apart. These micro-pieces of the discussion actions were integrated into the whole picture for the further analysis. During the first lesson the teacher was at the beginning of her experience of managing the whole-class inquiry-based discussions. Development of the teacher's proficiency at managing the whole-class discussion developed in the course of her teaching experience without any professional-development intervention. Thus we consider our findings to be an indication of the act of teaching being an opportunity for teachers' professional development. The type of analysis that we suggested in this paper provides additional evidence of how teachers may orchestrate classroom discussion. We tried to describe what it mean that the teachers become more reflective and more flexible when orchestrating the whole-class discussion.

In this study we applied Shoenfeld (1985) schemes of analysis of solving mathematical problems to solving teaching problem (in terms of Lampert, 2001). Futhermore we would like to pose the following analogy between mathematical problem solving and teaching problem solving. As Shoenfeld (1985) found that one may effectively teach algorithms whereas it is difficult to teach the heuristic for when to apply the proper algorithm. This

use of heuristics distingueshes the expert problem-solver from the novice. We suppose that teacher actions may be teachable; however, it may be difficult to teach a teacher when to apply a particular teaching action. In this sense we would like to speculate that teacher actions are of heuristic nature, i.e. are not describable by algorithms. At the same time we suggest that our categories may serve as benchmarks in planning and analysing discussions and may be useful in different professional development programs for mathematics teachers that focus on the issue of whole-class inquiry-based discussion.

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