

TOWARD A METHODOLOGY FOR EXPLORING MATHEMATICS PRESERVICE TEACHERS' LEARNING FROM A SOCIOCULTURAL PERSPECTIVE

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This paper describes a methodological procedure for characterizing mathematics preservice teachers' learning from a sociocultural perspective. The procedure involves interpreting some aspects of Wenger's theory of social learning, adapting them to preservice teacher training, and making this adaptation operational for coding and analyzing audio recordings of a group of preservice teachers working at home. An example of a research result obtained using this procedure is presented.

Keywords: Preservice mathematics teachers' training; Preservice teachers' learning; Research methodology; Sociocultural perspective; Wenger

Hacia una Metodología para Explorar el Aprendizaje de Futuros Profesores de Matemáticas desde una Perspectiva Sociocultural

En este artículo describo un procedimiento metodológico para caracterizar el aprendizaje de futuros profesores de matemáticas desde una perspectiva sociocultural. En este procedimiento interpreto algunos aspectos de la teoría social del aprendizaje de Wenger, los adapto a la formación inicial de profesores y los utilizo para diseñar instrumentos de codificación y análisis de grabaciones de audio de un grupo de futuros profesores trabajando fuera del aula. Presento un ejemplo de un resultado de investigación obtenido utilizando este procedimiento.

Términos clave: Aprendizaje de futuros profesores; Formación inicial de profesores de matemáticas; Metodología de investigación; Perspectiva sociocultural; Wenger

Sociocultural views provide new ways of conceptualizing the process of becoming a teacher (e.g., Borko, 2004; Lerman, 2001; Llinares & Krainer, 2006). Some researchers have explored preservice teachers' learning from this perspective (e.g., Gómez, 2006; Graven & Aurbough, 2003; Llinares & Krainer, 2006) and suggest that training programs based on it promote learning (Kilpatrick, 2003; Lieberman, 2000; Little, 2002). However, it is not clear how to make these learning theories operational from a methodological point of view. The researcher must examine the learning processes from a broader perspective and include many aspects of the participants' behavior that are usually not taken into account in more cognitive approaches to learning.

I tackled these methodological issues in a research project that explored the didactical knowledge development of preservice teachers in a methods course (Gómez, 2007). One of the studies in this project focused on the learning processes of a group of preservice teachers working at home on the tasks assigned in class (Gómez & Rico, 2007). I decided to explore and characterize this group's learning over the academic year based on some aspects of Wenger's theory of social learning (Wenger, 1998).

The preservice teachers were organized in groups. They performed several tasks during the course that involved the analysis of a mathematical topic taking into account the topic's multiple didactical meanings (Gómez & Rico, 2004) and which aimed to design a didactic unit¹. For each task, each group worked at home and then gave a presentation to the class using transparencies. I asked the members of one group to allow me to audio record their interaction as they prepared their presentations for the course. This group, of four male students, had the quadratic function as its topic of study. Eight meetings were recorded, producing 18 hours of recording.

My problem was then to design instruments that would allow me to code and analyze the transcriptions of the recordings in terms of Wenger's theory of social learning. In what follows, I first describe the features of Wenger's theory on which I based the inquiry. Then, I present the methodological procedure I established to code and analyze the audio recordings based on that theory. Finally I provide an example of one of the results of this analysis.

LEARNING AS A SOCIAL PRACTICE

Wenger's social theory of learning is based on four notions: meaning, practice, community and identity. Wenger introduces meaning as a way of talking about our (changing) ability—individually and collectively—to experience our life

¹ In Spain, the expression *didactic unit* refers to a series of lessons organized around a particular topic. It does not refer to only one learning objective, but it is usually concrete enough to require no more than five lessons. Its coherence is given by the subject matter and the learning objectives the teacher sets for it.

and the world as meaningful. The negotiation of meaning emerges from the interaction of two processes: participation, the process in which we establish relationships with other people, define our way of belonging to the communities in which we engage on some enterprises, and develop our identity; and reification, the process of giving form to our experience by producing objects that congeal this experience into “thingness”. Every community produces abstractions, tools, symbols, stories, terms and concepts that reify some of the practice in congealed form. For Wenger, practice is a way of talking about the shared historical and social resources, frameworks, and perspectives that can sustain mutual engagement in action. Practice is the source of community coherence and the process through which we experience the world meaningfully. It does not exist in the abstract; it exists because people engage in actions whose meanings are negotiated. A community of practice represents the smallest unit of analysis in which one can include the negotiation of meaning as a mechanism of learning. It is a way of talking about the social configurations in which our enterprises are defined as worth pursuing and our participation is recognizable as competence. The idea of a community of practice is based on three notions: mutual engagement, joint enterprise and shared repertoire. The notion of identity is introduced as a way of talking about how learning changes who we are and creates personal histories of becoming in the context of our communities. Learning as social practice can be characterized by the three notions shaping the community of practice. Learning in practice implies mutual engagement in the search for a joint enterprise with a shared repertoire. That is, learning emerges to the extent that (a) different forms of mutual commitment evolve; (b) the enterprise is understood and refined; and (c) a shared repertoire, style and discourse are developed.

FROM SOME ASPECTS OF THE THEORY TO DIMENSIONS AND CATEGORIES OF ANALYSIS

The methodological problem lay in the design of instruments for coding and analyzing the audio recordings in terms of the three dimensions that characterize the emergence of learning as a social practice. The instruments should satisfy at least two conditions: to ensure both the relevance of the issues that might emerge concerning the group’s learning and the completeness of the inquiry and analysis. Furthermore, the instruments should enable the interpretation of results to focus on the theory and “produce well-grounded assertions regarding social practice and learning” (Little, 2002, p. 920). The first step in this process was the construction of a set categories of analysis based on the theory. These categories were to link the central notions of the theory in which I was interested and the code set that would determine the instrument for exploring, selecting and articulating the information available. These categories emerged from a detailed and purposeful reading of the theory. After an initial review of the transcriptions of

the audio recordings, I interpreted and selected notions and aspects of the theory based on the information on the audio recording. In this way, I produced several versions of a list of categories until the list was consistent with and meaningful to the information. The following final list emerged:

- ◆ *Mutual engagement*: environment, identities, relationships, and meaning.
- ◆ *Joint enterprise*: external conditions, discourse, enterprise, and responsibilities.
- ◆ *Shared repertoire*: working routines and resources for the negotiation of meaning.

Keeping in mind the meaning of the categories within the theory, I identified a set of questions that characterized the categories and suited both the phenomena I wished to study and the information available. I identified and articulated these questions in a cyclical process in which, while coding the information with a given version of the questions, I corrected, deleted and added new questions to the list. Figure 1 shows the final version of the questions for the dimension of mutual engagement. These questions are framed in terms of the performance of the group of preservice teachers studied. They organize the code set that I will introduce below.

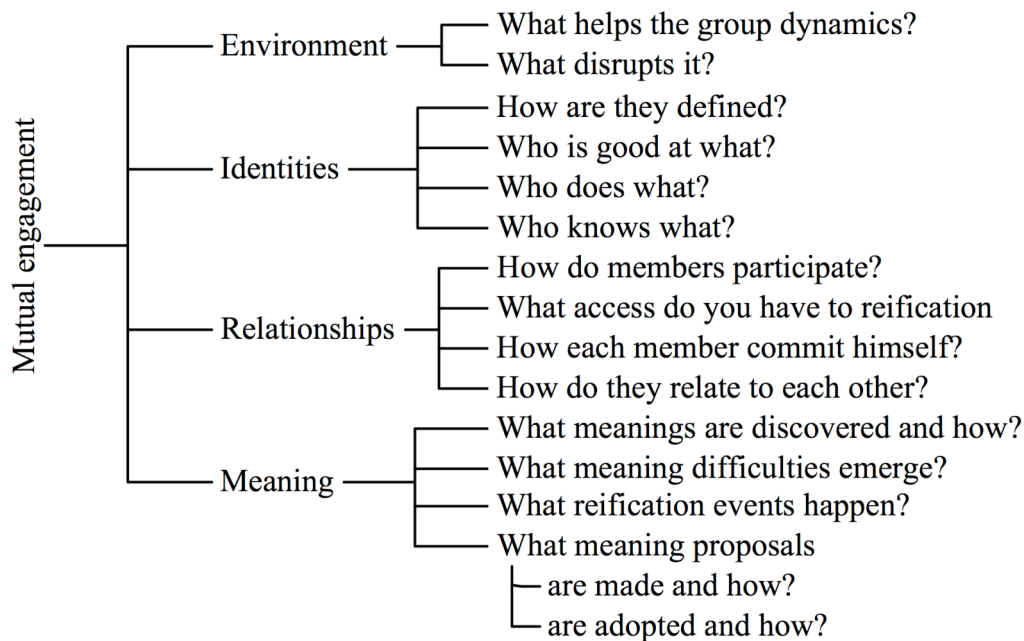


Figure 1. Questions for the dimension of mutual engagement

CODE SET

I developed a preliminary set of codes starting from the questions described above. This code system evolved in the process of coding the transcriptions. For instance, after coding the transcriptions of the first two sessions, I observed the need to introduce a code in the “external conditions” category of the mutual engagement dimension. The purpose of this code was to identify episodes in which the members referred to the way the task at hand was formulated. This external condition affected their performance. The final code set contained 94 codes. Table 1 presents some examples of the codes. Their meaning establishes the characteristics of the episodes to which the code is assigned.

Table 1
Examples of codes

Code	Meaning
Teaching experience	At least one member refers to his teaching experience
Who is good at what?	The group identifies a member as competent for a task or that member proposes himself as such
Discussion steering	One of the members organizes or steers the group discussion towards a particular issue
Meaning confusion	There is evidence of confusion in one or more members with respect to the meaning of a given issue
Commentaries on transparencies	The group refers to the educator’s written commentaries on its transparencies
What is valued?	Evidence of aspects of the work or the discussion that are valued by the group
What are the working routines?	Working routines are established within the group
Complexity of the conceptual structure	References are made to the complexity of the conceptual structure
Connections	References are made to connections among representation systems

CODING PROCESS

In the coding process, I identified, registered and characterized the episodes. An episode is a segment of the transcription, of variable length, that contains statements from one of the members or an exchange of statements between several

group members. Its coherence as an episode derives from its treatment of one idea or message. Thus, some episodes both refer to a particular idea and form part of a larger episode that refers to a more general idea. More than one code may be assigned to an episode.

I produced a database for registering the results of the coding process. Each record contained all of the characteristics of a given episode-code pair, as well as a comment for that episode. I also made notes that described my interpretation of the interaction and identified its most relevant aspects. The following is an example of an episode that I coded with the codes corresponding to personal relationships, leader and complementary participation. In this episode, one of the members, whose performance represents complementary participation, addresses the leader's authoritarian attitude. I assigned the following commentary to this episode: "Again, there is tension: They criticize the leader explicitly. 'He knows everything because he teaches'":

P1: Now, he is a specialist. Since he teaches, he now thinks that everything is clear.

After coding, there were 7,412 records in the database. These correspond to 2,606 episodes (since several codes could be assigned to a given episode). Figure 2 shows the coding process I have described.

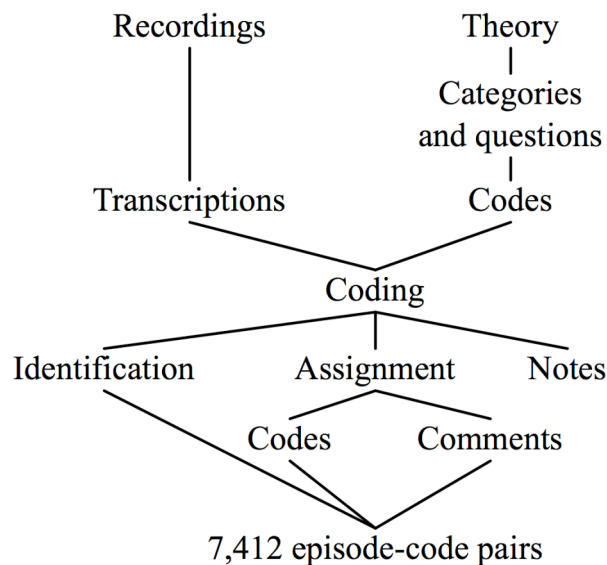


Figure 2. Coding process

The database design allowed me to produce and organize my comments on the episodes. From there, I summarized the transcriptions of each session. The summaries enabled me to identify the most relevant issues. These issues represented my characterization of the group's interaction. This list of issues was produced by synthesizing the episode-code pairs, taking into account the theory (through the categories and the questions) and the additional information that I registered

during the coding (comments and notes). Figure 3 shows a diagram of this process.

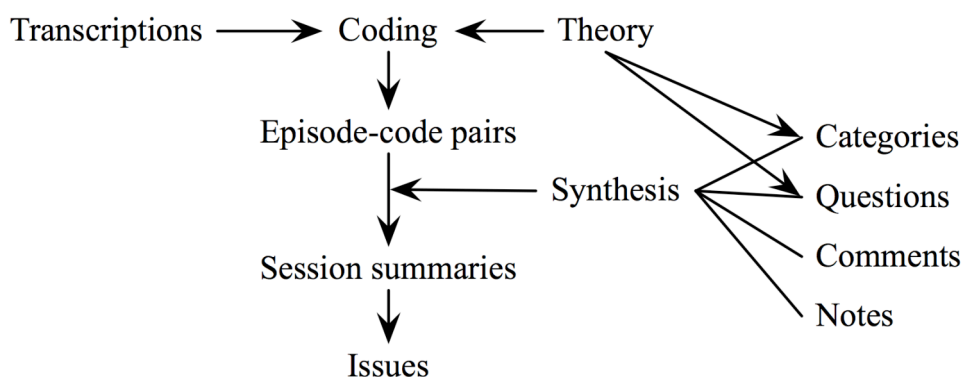


Figure 3. Identifying the issues

For example, the analysis in Figure 3 shows that one of the issues was the fact that the group had a leader and that his performance determined several aspects of the learning process. I thus had to characterize the leader and his relationship to the other members of the group. I summarized the list of issues in a set of phrases (role of leader, role of comments on transparencies, importance of connections among systems of representation, etc.), which in turn summarized the 950.5 minutes of the original audio recordings.

I identified 32 issues. The following are the issues corresponding to the dimension mutual engagement:

- ◆ Environment: teaching experience, practice course, and textbooks.
- ◆ Leader: characterization of leader, complementary participation.
- ◆ History of the tension in the group.
- ◆ Meaning: search for meaning, meaning confusion, meaning conflicts and resolution, evaluation: a story of meaning conflict, meaning discovery, reification events.

I obtained the list of relevant issues through a process of synthesis. Figure 4 shows a diagram of this process in terms of the databases used.

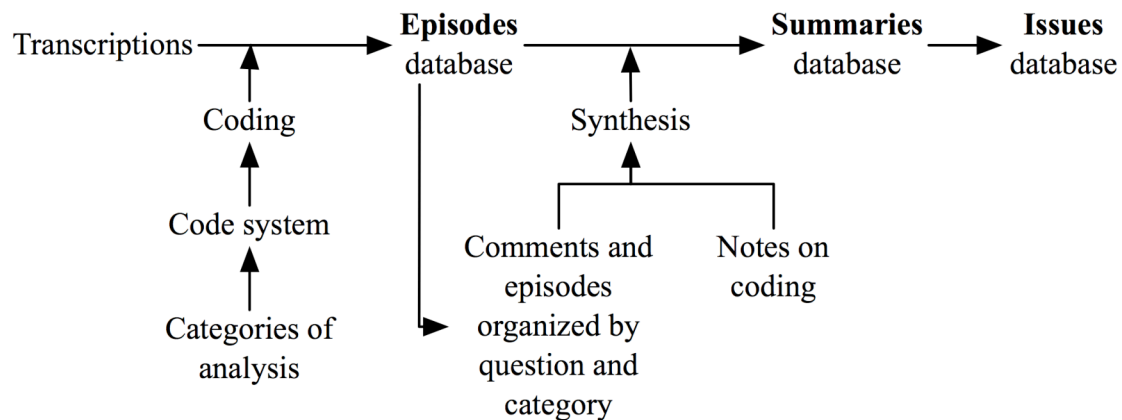


Figure 4. Synthesis: From transcriptions to issues

ANALYSIS

The issues database was the starting point for a process of analysis. For each issue, I wanted to (a) describe the issue, identifying its main characteristics and (b) identify the most representative episodes of those characteristics in order to provide evidence for the issue's characterization. To achieve these goals, I had to solve a new methodological problem. A given issue (e.g., the characterization of the leader and of his relationships with the other members of the group) could involve more than one code. Furthermore, for each code there might be a high number of records in the episodes database. For instance, the code "complementary participation" was assigned to 55 episodes and the code "meaning search" to 475. During the coding process, it was not possible to identify which episodes would become representative, since at that point I did not know the issues I needed to analyze. The problem was thus to design a procedure that would allow me to select those episodes.

I designed a new database with the information contained in the summaries described in the previous section. For each topic in a summary, a record of the database was created containing the dimension, category and codes corresponding to that topic. The resulting database contained 754 records. To select the representative episodes to characterize a given issue, I implemented the following procedure:

1. Identification of the statements in the summaries related to the issue.
2. Identification of the codes related to the issue.
3. Search for all episodes related to the issue (by code and by comment).
4. Review of the list of episodes based on related comments: first selection of episodes and assignment of categories for its characterization.

5. Review of the transcriptions of the selected episodes (new selection and assignment of categories).
6. Final selection of the representative episodes.
7. Description of the issue in terms of the characteristics identified.

GRAPHIC SIGNIFICANCE OF THE PARAMETERS

This section provides a brief glance at one of the study's results². The graphic meaning of the parameters of the symbolic forms was discussed in the session on preparing the didactic unit. Up to this time, the meaning of the connections between symbolic and graphic systems of representation had been general. The specificity of these connections (with respect to the parameters) arose from the need to design in detail the activities that would be proposed to the students in the sessions to make up the didactic unit. Tackling this problem generated confusion and made explicit some of the difficulties that the preservice teachers encountered in the mathematical handling of their topic. These difficulties became evident in their use of the graphic significance of the parameters of symbolic forms.

The doubts and confusion on this topic can be seen in the following episode³, in which questions arose about the role of the parameters in locating the intersections of the function with the x -axis:

- P4:* So, the points of intersection with the x -axis influence the other coefficients of the function. Don't they?
- P2:* Yes, but...
- P3:* Wait.
- P4:* Let's see.
- P3:* What are you trying to say?
- P4:* Bartolo [P2] is saying... Bartolo is saying that, when you have just seen the general characteristics..., such as, for example, the intervals of increase and decrease, these depend on the lead coefficient, as it says here. That's what you're saying.
- P4:* Then, I say the same thing that is being said about the lead coefficient; when you see the points of interaction, you will have to say how they influence all of the other coefficients. Because here is the influence. Be-

² For ease of reading, I have not included the references to the location of the episodes that support these claims. For instance, each sentence in this paragraph is a statement that has at least one representative episode supporting it.

³ The examples of codes that follow refer to particular concepts and procedures in the methods course. They formed an important part of the group's shared repertoire.

cause in the other one, it's true that they influence all of them. In the points of intersection, all three have influence. Don't they?

When the group reflected on the role of parameter a in the expression $f(x) = ax^2 + bx + c$, they concluded that all of the characteristics of the graph of the function depended on this parameter. But, as is natural, they encountered the greatest difficulties with the meaning of parameter b . These difficulties appeared at the beginning of the session, when one of the members asked explicitly about the graphic meaning of this parameter. In discussing this topic, they decided that this parameter alone had no influence. The group then reverted to the algebraic consideration to focus the graphic meaning of the parameter in its influence on where the function intersected with the x-axis. Finally, they established that this parameter influenced the horizontal translation of the vertex, but they did not realize that this influence was linear, while the effect on the vertical position of the vertex was quadratic:

P2: When the sign of the coefficient of x is negative, the thing is translated..., always to the right, I think.

P3: ...It would be $x - \dots$. Let's see; if it's negative, it is to the right. The positive... (Several people talk at the same time).

P2: The positive to the left. Yay! That's it. There you have it. () the b . (Several people talk at the same time).

P4: If it's negative, it's to the right.

In the end, some of the members did not understand the details of the discussion, and the confusion was not clarified in the group, although the didactic unit contained activities that tackled the problem:

P2: $x^2 - 1$.

P3: You understand, don't you?

P1: No, I don't.

DISCUSSION

The methodological issues and procedures involved in mathematics education research are not usually described in detail. Detailed descriptions are usually left to doctoral dissertations and in many cases refer to methodologies already developed. However, in this study, the problem was twofold. First, it was necessary to interpret Wenger's theory of learning as social practice in the context of pre-service training of mathematics teachers. Second, this interpretation had to be made operational: I needed to design coding and processes for analyzing the information available.

My purpose was not to identify some episodes that could exemplify some aspects of the group's learning in terms of Wenger's theory. Rather, it was to give specific meaning to the ideas that articulate learning in communities of practice in the context of preservice training of mathematics teachers and to design instruments for codification and analysis of this complexity. This kind of procedure was time-consuming, but it enabled me to tackle a large body of data systematically and obtain results whose validity was based on the procedure itself.

The results show a complexity behind the in-class presentations of the groups of future teachers and their projects that is inherent to the development of a community of practice. By analyzing this complexity systematically and in detail, I identified and characterized many aspects of the social learning of a group of future teachers. The level of detail that this methodology allows makes these characterizations interesting and important in themselves. They illuminate dimensions of the initial training of preservice mathematics teachers that often remain opaque in the research literature. For example, they enabled me to understand the processes of negotiation of meaning that materialized in the transparencies and in the group's final project. They also revealed the different positions of the participants, their questions and confusion, the conflicts they had to face and resolve, and the plans and techniques they developed to complete the tasks they were assigned. Finally, the in-depth analysis of the transcriptions illuminates the group's progress in its commitment to the joint construction of the meanings that its members believed necessary to satisfy both the requirements of the course and their interest in becoming mathematics teachers⁴.

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⁴ More detail on these results can be found in Gómez (2007).

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