

LEARNING IN VIRTUAL ENVIRONMENTS: A METHODOLOGY FOR THE ANALYSIS OF TEACHER DISCOURSEⁱ

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Abstract

Attention to the teleinteractive processes aiming at professional development is an area that currently awakens a considerable interest. Nevertheless, the analysis of the various teachers' meanings collaboratively shared in a given virtual community is still incipient in the field of educational research. In this paper we analyse qualitatively electronic discourse in virtual seminars and present contributions of distance interactions for teachers' education. The discussion forum as a communicative space presents and develops important discursive singularities among all the communicating agents involved in the process of professional development.

Keywords: Distance Education, *E-Learning*, Virtual Seminar, Professional Discourse

INTRODUCTION

In the past two decades, technological and social changes have mutually affected each other more rapidly than in the past. These swift changes have necessarily impacted on education in the classroom and on how teachers develop professionally. Since teachers represent crucial actors in the educational process, technological and social transformations have compelled researchers to understand the effects of these changes on the professional development of teachers and to investigate ways of enhancing interactions among teachers to promote further changes in their Professional Content Knowledge (PCK). The research reported here examines the contribution of interactions in virtual environments on the PCK of mathematics teachers involved in a distance-learning program.

Learning through virtual environments has been the subject of recent research on distance education. Sakshaug (2000) reports that research on mathematics education at a distance parallels the development of telecommunication technologies and that the research literature in this area has two important moments. At first, studies paid attention to how students learn mathematics in virtual environments. Later, researchers focused on how students learn mathematics when technology is a learning tool and when students work independent of interactions with teachers. According to Sakshaug, research ought to contribute effectively to the teaching-learning process in distance education in mathematics. She proposes that researchers should attend to how students learn in virtual environments, when technology is used as a mediator of distance interactions between teachers and students.

A close examination of the literature, allows us to distinguish a third important moment in the literature on teacher education at a distance. In this moment, investigators analyse interactions to understand learning when students, teachers, and the mediating technology are all three studied simultaneously. Some researchers examine the use of telecommunication to promote dialogue and change in teachers' thinking (Selinger, 1997; Blanton, 1998). Bitter & Pryor (2000) have studied a Web-based environment intended for the professional development of mathematics teachers and propose elements of an effective interactive multimedia environment. More recently, Ponte et al. (2002) described the work undertaken in a course on information and communication technology in a pre-service program for secondary school mathematics teachers and emphasised contributions of the course for the development

of professional knowledge and professional identity. Santos & Ponte (2003) present some evaluation results, showing how teachers adjusted to this new teacher education format and how they reacted to the papers and tasks proposed about “Learning mathematics by investigating”. The researchers conclude with a discussion about the potential of distance education as an in-service opportunity for mathematics teachers to develop principles of collaboration, reflection and exploration and inquiry.

Despite these three moments in the literature on mathematics learning through distance education, Barberà (2001) notes the absence of research that analyses the teaching and learning processes in virtual contexts from a constructivist perspective. In addition, Rodríguez-Ardura & Ryan (2001) add that an adequate theoretical framework on teaching and learning systems in virtual environments still needs to be built and that specific motivation, support, and guidance strategies have to be defined. The present research intends to contribute a method of analysing the PCK of mathematics teachers, examining interactions among them and with researchers where technology mediates the interactions in a specific virtual geometric environment.

In this report, the main research questions addressed concern the cognitive contributions of electronic discussion forums for teachers’ PCK in geometry. Specifically, there are two research questions:

1. What teacher interventions and hypertextual links can be identified and how do they contribute to their professional reflections?
2. What elements of PCK occur in cognitive nodes?

In this study, we elucidate discourse structures by constructing hypertexts of a discussion forum and present suggestions for educational researchers interested in teachers learning in virtual environments.

THEORETICAL FRAMEWORK

The theoretical framework of the research described here is based in two perspectives: (1) metacognitive learning through interactive writing and (2) the construction of teacher discourse in interactive hypertextual virtual mathematics communities.

Metacognition and learning through interactive writing

In our research, text and hypertext are important discursive components in the negotiation and construction of professional meanings. Powell & López (1989) note that text construction necessarily involves authors in ordering both thoughts and feelings about things and about thoughts. For instance, as teachers write and rewrite texts, they and their readers (the researcher, the teachers themselves, or their colleagues) review their knowledge to understand and reflect on the meaning of the texts. As Powell (2001) claims, in the recursive process of (re)reading and (re)writing, the researcher as well as teachers examine and reflect, react and respond differently at each iteration and, consequently, each time, they further develop their PCK.

On the point of discursive relations, Lemke (1997) emphasises that any text exists within the context of an activity and creates semantic relations with other textual elements that form part of the discourse. In this sense, therefore, the content of a professional development course determines various textual relations and establishes a series of semantic representations that can be influenced by, among other actors, the designer of the course. The course designer along with participating teachers can create conditions that enable them to reflect metacognitively (Santos, 1995; Santos-Wagner, 1999) about their own attitudes and beliefs concerning mathematics, about their pedagogical practices, and about their mathematics teaching and learning process, as well as to think critically about assessment.

Teacher discourse in interactive hypertextual virtual mathematics communities

Conventional and hypertextual environments have important differences for both research and learning. In virtual environments, the elements of a communicative message continuously build and rebuild on each other, in both scale and universes of meanings. In such environments, hypertext refers to the multiple formats, ways, and channels that one accesses information as well as to the social-technical processes of information access (Lévy, 1993). Lévy (1999) adds that in virtual spaces teachers are grouped into clusters of common interests and professional problems and that, in spite of not being in face-to-face contact, this community is full of passions, conflicts and friendships. Furthermore, he emphasises that hypertext can be a valid metaphor for environments where the exchange of semantic representations are continually in play.

As discourse is composed of semantic representations, van Dijk (1985) points out that there are pragmatic conditions for every discourse; that is, discourse has enunciation characteristics and purposes such as who elaborates it, to whom it addresses, and for what is it intended.

Contrary to the linearity and inalterability that characterises conventional texts, hypertexts represent a more complex discourse modality. Hypertexts allow for the organisation of information in direct content blocks called nodes, connected through a series of links that enable the user to access instantly target information. Moreover, links can form multiple routes for a user to access information (León, 1997). As León adds, hypertext can emulate the organising and associating capacities of human memory, especially in the way it relates concepts to each other. Nevertheless, hypertext does not hold value over conventional text. The point is to highlight the differences between the two discourse modalities for the construction of teacher knowledge in virtual communities. The complexity of the hypertextual systems, depending on the needs and objectives set by the designers and users, favour flexible, dynamic, and meaningful communicative environments.

The connection among hypertextual systems occurs through links. Jonassen (1986) distinguishes three types of links: hierarchic, conceptual, and referential. *Hierarchic links* presuppose a given relation of order among two or more communicating nodes. The relation between the nodes is one of mutual dependence and the content of one node is a prerequisite for the next node. In a system of *conceptual links*, there is a central node that may be defined and explained through other nodes. This central node can be supported by several nodes or by a group of nodes and can be accessed from different places. Nodes that are linked conceptually complement each other. Unlike the first two types of links, *referential links* are independent and non-hierarchical. The information between two nodes can be interpreted independently from the existing information in the other nodes. Below is an illustration for each type of hypertextual link, as proposed by Jonassen.

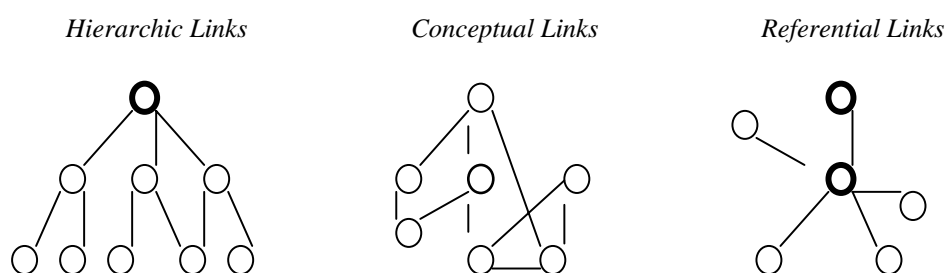


Figure 1. Jonassen's three types of hipertextual links

In Jonassen's typology, nodes are organised units of information and fundamental activities. They constitute hypertextual trajectories to obtain data. These data can be analysed critically and become constructed knowledge (Gall & Hannafin, 1994). Nodes that generate a broad discursive network and whose content is referenced and reconstructed through the virtual discussion are called cognitive or communicative nodes (Bairral, 2005). Cognitive nodes can be created through the different hypertextual links of Jonassen (1986) and more specifically the conceptual links, which constitute significant discursive moments of the interactive dynamic. Cognitive nodes are interrelated and maintained as basic referential knowledge. As a research tool, they are enough to give investigators information about different cognitive-communicative relations sustained, complemented, or exchanged in a virtual discussion.

Through the years, researchers have shown interest in understanding different ways learning occurs through hypertextual systems. For instance, considering that learning is a reorganisation of cognitive structure, then we need tools for assessing cognitive structure, tools for depicting and displaying appropriate knowledge structures, as well as means for mapping that structure onto the learner's knowledge structure, Jonassen (1988) emphasises that hypertext is a promising tool for learning¹. Using the ideas of Jonassen (1986, 1988) about hypertext as well as those of other authors, Gall & Hannafin (1994) suggest a common language and attributes of hypertext and a framework for its study. They do not discuss a specific public. While the framework itself is an evolutionary product, it provides an integrated method for studying important relationships. It provides a structure within which research may be organised, allowing a more thoughtful analysis of the implications of past research conducted on hypertext learning systems. According to the authors, the framework can also be used to identify future areas of research as well as to examine how research studies may be designed. My research presented here adds a qualitative analysis centred on the construction of discourse types and their implications for the construction and identification of cognitive nodes in virtual discussion among teachers.

Rouet (1997) underscores the need to consider information processing strategies and skills of students. Niederhauser, Reynolds, Salmen & Skolmoski (2000), stressing the importance of cognitive flexibility in hypertextual navigation, examine quantitatively the effects of different navigational patterns on the learning of undergraduate students in computer science in hypertextual environments. In the realm

of mathematics teachers' professional development, Horvath & Lehrer (2000), interested in technological mediation, study development and change in instructional practice when primary school teachers are provided with information about students' cognitive processing. Horvath & Lehrer elaborate a multimedia system—the *HyperMeasure*—in which they made available to teachers videoclips of students in classrooms working on linear, area and volume measure. Besides individual differences in professional development of the teachers, Horvath & Lehrer observed that the implemented system effectuated pedagogical learning of teachers and that the teachers showed improvement in three types of skills: (1) to perceive and determine that principals of measurement, (2) to see students work in real time and perceive how they learn and what they need, and (3) to recognize artefacts used by students and the implications of these artefacts on student thinking. In previous research, Giménez et al. (2001), undertake a qualitatively analysis the cognitive value of an electronic discussion forum—closed list of e-mail exchanges—among post-bacholarette teachers, attending a course in the psycho-pedagogy of mathematics. More recently, Bairral (2003) presents contributions and idiosyncrasies of teleinteractive dynamic through a continuous hypertextual construction of electronic messages for teacher development in mathematics.

In our research, besides the work dynamic on formative virtual environments, the contributions of discussion forums, and the messages exchanged among teachers and researcher were hypertextual. The hypertexts shaped by teachers allow for a progressive construction of a wide web of argumentation that are always present and available in the specific discourse community. Moreover, the hypertext can be oriented by any member of the group and monitored by the researcher.

An aspect to take into account in studies centred within hypertextual systems is the narrow dependence of the hypertext in relation to user characteristics (Léon, 1997). From this point of view, we were interested in monitoring and analysing the simplest case of professional communication in the discussion forum, which was established when the teachers did not make use of the complementary means in the environment (programs, files, and so on), there was no visual contact between them and they did not participate in real time.

METHODS

Design

Since August 2000, with collaboration from the University of Barcelona (*Universitat de Barcelona*) our research project, based at the Rural Federal University of Rio de Janeiro (*Universidade Federal Rural do Rio de Janeiro*), is part of a larger distance learning initiative² for practising teachers of high school geometry, whose students range in age between 11 and 14 years. Teachers participate in our project for a total of fifty hours. The virtual environment is structured around 6 hypertextual axes (Jonassen & Rahrer-Murphy, 1999): (1) the activity that invites teachers to review their own geometric knowledge and professional activity, (2) observation of the role that everyday life plays in different geometric activities, (3) recognition of students' cognitive processes, (4) the determination of material for each subject, (5) summaries of the organisation of the content of units, and (6) continuous self-assessment. The geometric content was developed in eight units (areas and two-dimensional forms, spatial relations, geometric constructions, angles, symmetry, similarity, and geometric reasoning). Figure 2 contains the principal page of unit 1 and the hypertextual axes.

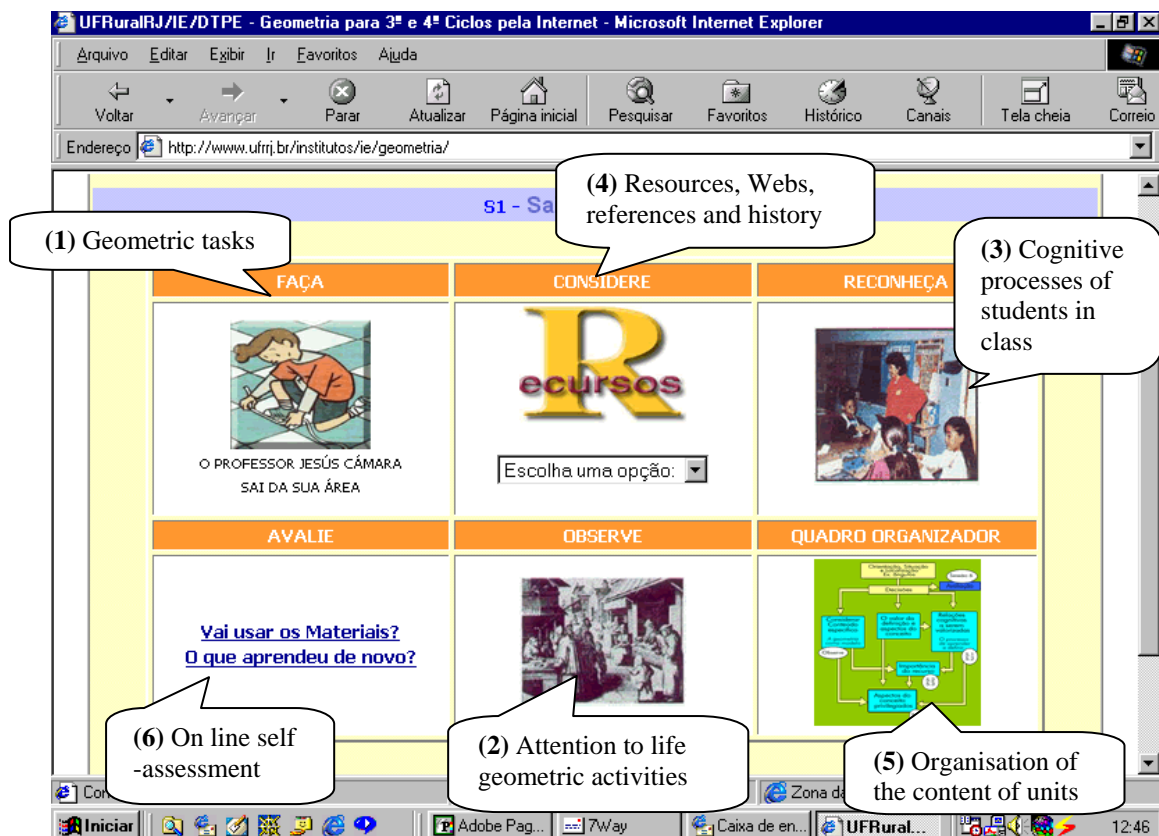


Figure 2. Page of Unit 1 and hipertextual axes

Participants

The course upon which this study is based has two iterations and the participants were attending the second iteration of the course. They are practising mathematics teachers, enrolled in geometry course through distance learning over the Internet. The distance learning course is particularly important since many Brazilian teachers live far from big centres of teacher education and, consequently, have fewer opportunities for acquiring and improving their PCK in geometry. The participant consists of twelve teachers, ranging in age from 33 to 50 years, including only one male teacher. From informal interviews, the teachers agreed to participate in the course so that they could improve their knowledge of geometry and because of their curiosity about distance learning. They had no previous experience in any type of e-training, had different years of teaching experience, different academic backgrounds, and were from different parts of the country.

The discussion forum as a space for teachers' reflections

Data for this research report was taken from discussion forum. The results of previous research indicate that one way of developing a collaborative hypertextual system is the use of virtual seminars or discussion forum (Giménez et al., 2001). We used the discussion forum as a means to collect data about participants' PCK in different moments of the course and also as an essential source of data to analyse the professional development process of collaborative teacher discussions.

In the current research project, the discussion forum is one of several communicative spaces used in the overall distance education project. Teachers could freely access all the interventions in the forum, reflect upon them, and contribute new interventions. In the discussion forum, participation occurred in deferred time without the exchange of files or programs.

Data analysis

Interaction through the Internet constitutes a sequence of personal strategies and actions that are carried out according to the different theoretical and methodological conceptions of teachers and researcher. By interaction we mean any type of

communication among participants in the virtual environment. We carried out an interpretative analysis of the exchange of electronic mail, constructed with hypertextual characteristics. Similar to van Dijk (2000), we considered that the contributions to the discussion forum are sequences of reflections and establish semantic relations among the people who interact in the forum. In each interaction, it was possible to identify new information on elements of subject's professional knowledge. This information was semantically and hypertextually related to the contents of another contribution to which the participant refers, or to another context in which the participant is acting³. An example of these ideas is in the following sequence (part of schema 1) between three teachers (M, Su and Ci).

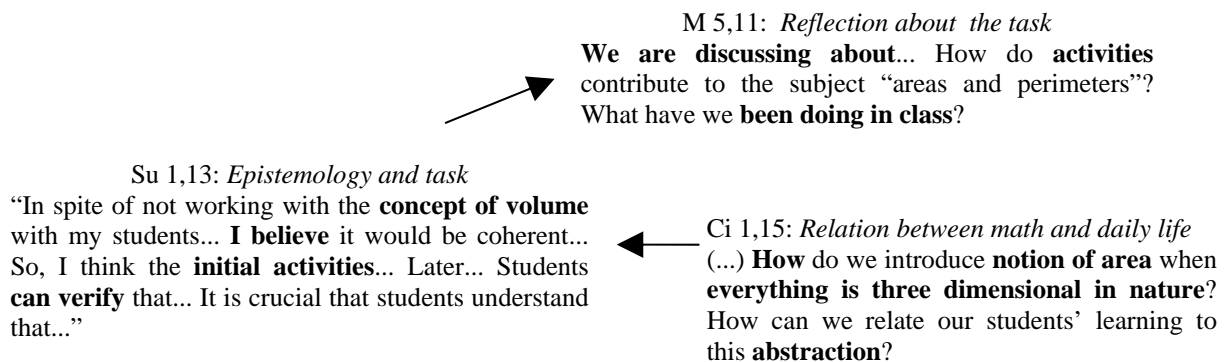


Figure 4. Sequence of three interactions

As we can see, teacher M clarifies (5,11) an issue and stimulates the others with a question. In her thirteenth contribution to the forum and her first (1,13), teacher Su, referring to M (5,11), underscores the importance of working with the concept of volume as an occupied space, gives an example, explores a task with capacity measures, and suggests other lessons. She also stresses the importance of area unit (square meters) and of volume (cubic meters). Continuing the collaborative discussion, teacher Ci reflects on the relationship between mathematical concepts and daily life experiences.

Contributions to the discussion are recorded thanks to technical characteristics of the kind of distance learning. As for as the discussion forum, the teachers were required only to participate at least once a week. Below are the procedures followed for the analysis of our data:

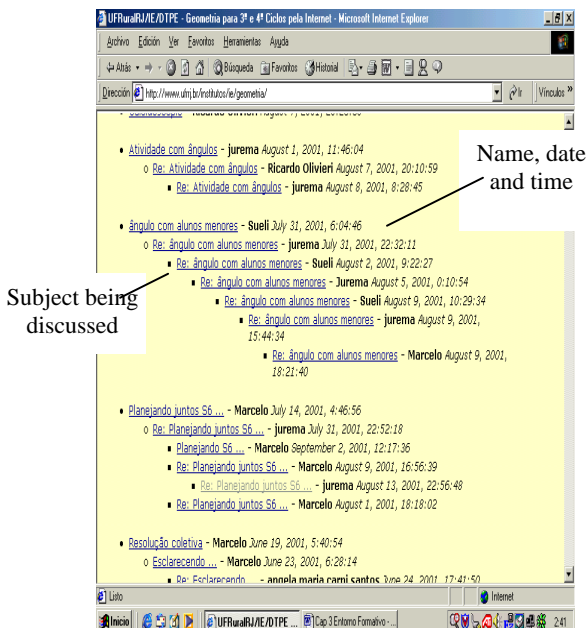


Figure 5. Page from the Discussion Forum and procedures of analysis

Procedures

1. Creation of a specific file for the contributions to the forum, by numbering and coding them;
2. Transference of contributions to the researcher's diary in order to complete them with constant remarks and analysis;
3. Characterisation of contributions;
4. Summary of contributions and confection of web-like schemata to analyse the dynamic of the debate as hypertextual, and
5. Meta-analysis of parts of the debate in function of what was observed.

According to Lévy (1993), this world consists of signification's and hypertextual structures not only for communication but also for social-technical processes and of various other phenomena. The author adds that it can be a valid metaphor for environments in which the (re)construction of signification are constantly in play.

Following the work of Giménez et al. (2001), an a prior classification was constructed to identify the type of intervention that can occur in a discussion and influence the discussion-forum community, especially in the development of hypertextual links. We would wish to underscore the our taxonomy is strictly related to the objectives of professional development and that they were considered in the construction of the environment and it hypertextual axes. To characterise the teachers' contributions, we identified the following discourse types for both the teachers and the researcher: methodological description (Dm), mathematics content analysis (Ac), deductive argumentation⁴ (Ar), definition of terms (Df). We considered two approaches of critical reflection: general (Vg) and specific (Va) and three types of contribution from the point of view of debate management and professional commitment: group participation (G), teacher's (P), self-justification (Jp). This last type of message is a more individualised, reflective communication.

For instance, in the following message, we can identify⁵ the importance that the collective virtual discussion (G) has for the teacher when he expresses and socializes doubts (Du) about a concrete situation, analysing it mathematically (Ac):

This is my first participation at the forum and **I feel privileged** already for **sharing my experiences**. One **doubt** that I've always had (and I think **I still have it**) is how do I introduce the notion of surface **when everything is three dimensional in nature**? How can we relate the student's learning with this abstraction? *Teacher Cintia, Discussion Forum, March 26, 2001, 8:47:38*

Besides the ones that have been presented, there are examples and typologies of contributions that have been exclusively identified in the researcher's discourse: opening for collective reflection (Ap), welcoming address to the forum (Bi), asking for exemplification of what the teacher does in class (Ec), requesting to clarify ideas (Sa).

For instance, in the following intervention, we can identify that the writer values the proposed by a colleague (Va), develops an analysis of mathematical content (Ac), presents an specific example from his classroom (Ei), demonstrates knowledge of the problematic in the discussion (Mo), and proposes a question to the collective of teachers:

For me, the **difficulties that** Joana points out are a problem that is in "area" rather than in "perimeter". **My students** grasp easily that 342 m^2 is smaller than 1 km^2 , **but they** have trouble realising that $1 \text{ m}^2 = 0,01 \text{ dm}^2$. **Where is the problem?** What would you **suggest to me**? *Researcher, Discussion Forum, April 2, 2001, 10:56:46*

When summarising and interpreting each contribution (step 4, figure 3), we identified and analysed the key elements of the content of professional knowledge involved in e-learning. We have considered three elements: geometrical, strategic and affective-attitudinal (Bairral, 2002). The *geometrical aspect* comprises the teachers' reflections and meanings about the process of thinking mathematically. The *strategic knowledge* includes the reflections on learning, instruction and interactive processes. The *affective-attitudinal* element deals with the attitudes towards the teachers' self-learning and their students' awareness and social culture, flexibility, judgement, equity and values in teaching.

For example, feeling happy about being able to discuss with a virtual collective and being flexible to discuss, a teacher presented aspects relevant affective-attitude on her professional knowledge (see below). Making explicit a critical reflection about the

influence of daily life on students' learning, the teacher reveals her strategic knowledge as well as geometrical awareness:

This is my first participation at the forum and I feel privileged already for sharing my experiences. One doubt that I've always had (and I think I still have it) is How do I introduce the notion of surface when everything is three dimensional in nature?. How can we relate the student's learning with this abstraction? *Teacher Cintia, Discussion Forum, March 26, 2001, 8:47:38*

RESULTS

Interventions, hypertextual links and identified nodes

In the dynamic of the virtual forum, we identified the three types of hypertextual links (conceptual, hierarchic or referential) proposed by Jonassen (1986). All of them are important for collaborative teaching work and generate cognitive nodes. During the whole of the teleinteractive process in the forum we have identified three cognitive nodes, stemming from the participation of three teachers. Table I presents different elements of PCK evidence in the three cognitive nodes.

Table I Summarising aspects of PCK and typology in nodes

Node	Teacher	Typology	Elements of PCK in content of nodes
1	Ci 1,15	G, Ac, Du	-Relation between geometrical content and everyday life
	2Su 13,79C, Va, Ac, Du, G, Pr		-Example of integration between geometry – and daily life. Example: surface and volume
3	Ju 18,104	C, Pr, Ep, Ad, An	-Reasoning on the value of units of measurement -Appraises students' difficulties regarding the classification of polygons

To identify a node, besides considering the number of links to a node and the different kinds of teacher reflection that a node generates, we also have to consider the time in the development of the discussion that the teacher takes as a reference (direct or indirect link). For instance in **node 1**, from contribution 15 to 68, there are teachers' contributions that make explicit reference to the content of the node.

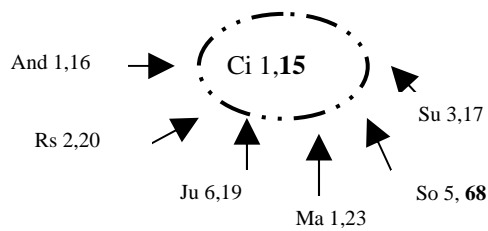


Figure 6. Node 1 and its respective contributions

From the content of **cognitive node 2** we can see references from contribution 79 through 91, and, in **node 3**, from 104 through number 111.

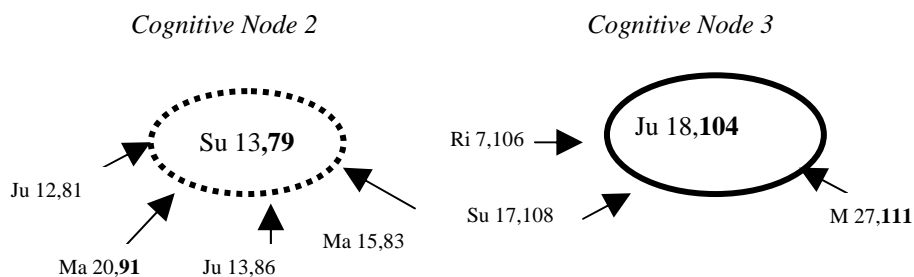


Figure 7. Contributions in node 2 and node 3

Besides identifying nodes in the communicative process of the environment, if we eliminate all the texts from schema 1, we can build schema 2, which reveals still further unique information about the collaborative work of teachers in the forum. For instance, in the interactive sequence of messages presented below, we can notice four characteristics of the exchange: (1) ideas considered or rejected and changes in the direction of the debate, (2) the regularity of teachers' participation, (3) types of links that were built, and (4) communication among teachers and spontaneous gathering of small groups.

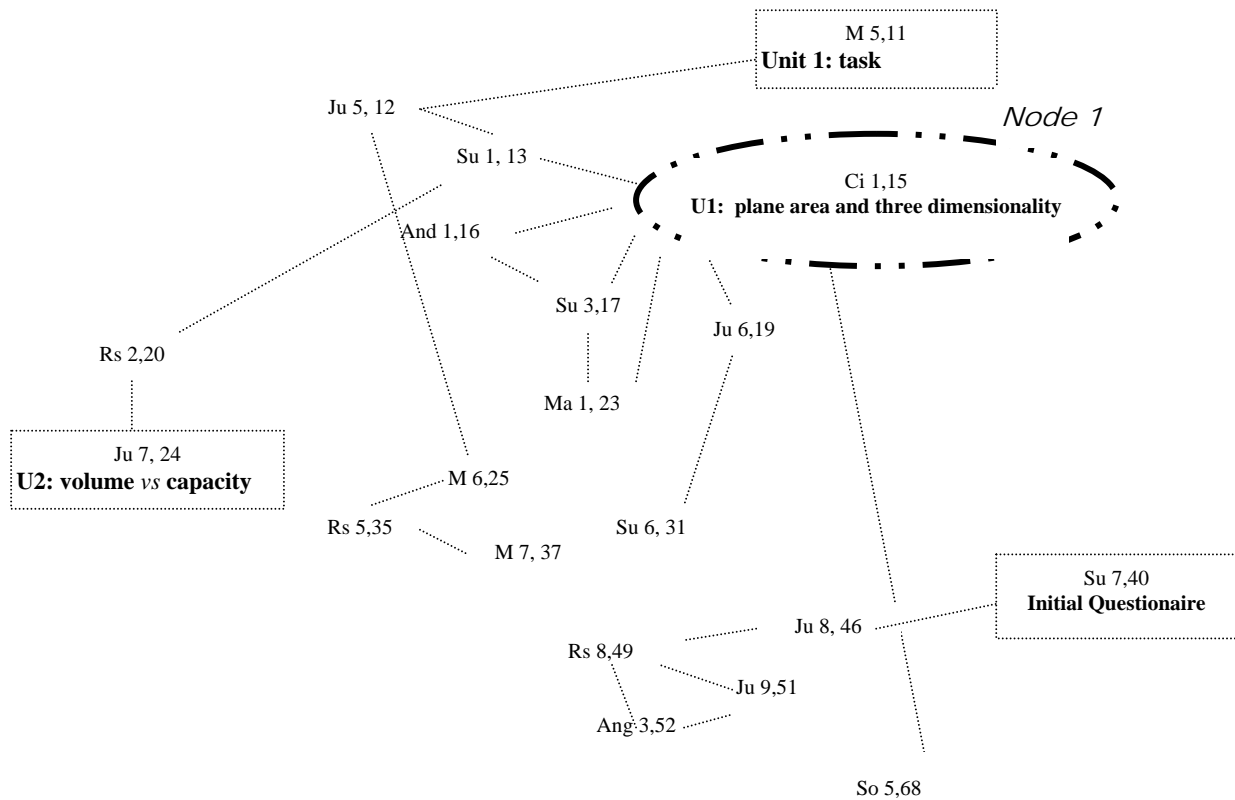


Figure 8. Example (part) of schema 2. Sequence: 11th “to” 68th

The analysis of interactions in the discussion forum has also allowed us to observe the potentiality of *argumentative* and *interrogative* contributions to generate mainly cognitive nodes (Bairral, 2005; Bairral, 2006; Jonassen, 1986) and to advance the metacognitive (Santos-Wagner, 1999) development of the teachers. Below we exemplify **node 1** with different links stemming from its referential content.

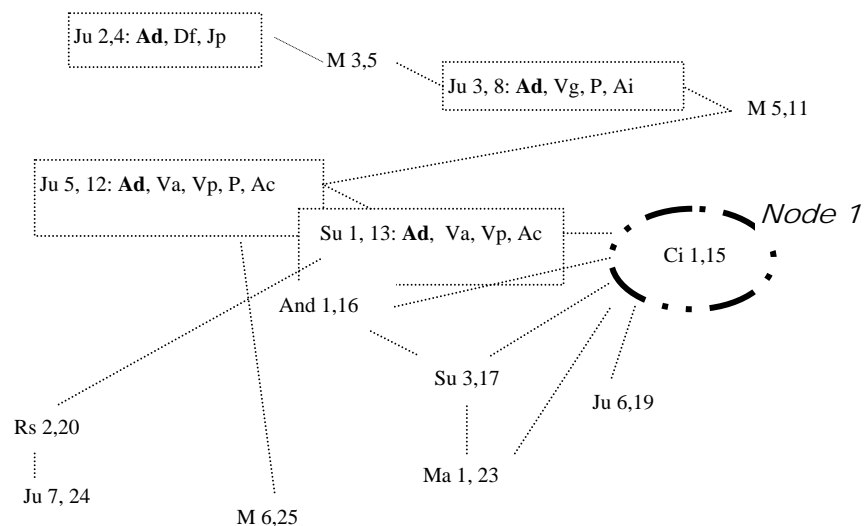


Figure 9. Example. Schema 2: node 1 – conceptual links and typology

The contributions of an *informative* character serve as a tool for continuous evaluation in the process. That is to say, the contributions that inform only (books, Websites, and so forth) are important as a controlling instrument on the part of the researcher and as a motivational component, but they have not been important for the argumentative continuity of the discussion and proved insufficient to inform the researcher about the process of the teachers' development in the virtual discussion forum.

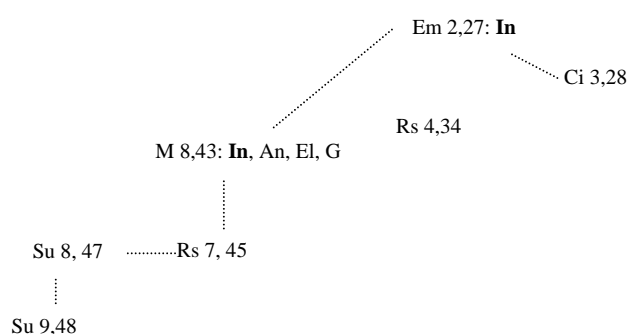


Figure 10. Example. Schema 2: hierarchical links

About the elements of PCK in cognitive nodes

The importance and need to maintain a continuous dialogue with the teachers could be perceived by contrasting the dynamic set at the forum and the contributions of mailed messages. Through the forum, the researcher can detect which teachers participate infrequently and contact them personally by e-mail.

As we have said, we identify in each node the elements of PCK. The analytical process has enabled us to identify these elements, traces them in a teacher involvement, and determine the extent to which they are deepened through interaction in the discussion forum. For instance, in cognitive **node 1**, what we observe is summarised in the following table:

Table II Dominant elements in node 1

Ci's 1 st contribution	Node Content	Dominant Elements
This is my first contribution at the forum and I feel privileged already! How do I introduce the notion of surface when everything is three dimensional in nature? How can we relate the student's learning with this abstraction?	-Relation between geometrical content and everyday life	-Geometrical -Strategic-Interpretative -Affective-Attitudinal

From this analytical perspective, we have seen that in the virtual discussion forum it is possible to develop metacognitive interactions in which teachers carry out a critical reflections that incorporate traits of three elements: geometrical, strategic and affective.

Concerning of PCK, we highlight the importance of the discussion forum as a communicative space in which we can identify how teachers contribute to the reasoning about what has been proposed, their way of seeing and facing—in their own personal time—a professional situation, their attention to the professional community and to the personal realm, their personal-professional meanings, built and refined from communication (Blanton, 1998) and from the virtual interactive processes (Barberà, 2001). In this process each teacher participated and contributed in different ways in the critical, virtual interactive process.

CONCLUSIONS

In this article, we are interested in elucidating discourse structures presented in an electronic discussion forum by constructing a hypertext of the contributions. From an analysis of these hypertextual contributions, we are presenting contributions for educational researchers interested in instruction through virtual seminars. Consistent with the research questions of this study, we conclude by discussing results about mathematics teacher education in virtual environments.

The interventions and hypertextual links and contributions for professional reflections

The typology created of the participants' contributions proved crucial for the researcher to identify elements in professional discourse that favour the continuity of discussion among the discourse community. In the case of contributions of mainly informative content (web pages, books, events, and so on) or where the teacher

participates for a more personal reason, we have seen that this type of contribution generates hierarchic or referential hypertexts. In argumentative contributions, teacher professional discourse uses general processes of inference to establish wider connections between current contribution and their own knowledge. Teachers' argumentative contributions generate a chain of cognitive nodes and a more detailed analysis of the issues being discussed. In discussion forums, all types of contributions are important for teachers' professional development, since teachers can reflect critically about their professional actions while also developing metacognitive reasoning skills. The interactions among teachers contribute to increasing their awareness of the causal instructional determinants that contribute to transformations of educational practice.

Referential schemata, besides being important methodological tools to contrast typologies and to analyse global structures (van Dijk, 1985) of teacher electronic discourse, can also be used as evaluating instruments in proposals that aim at professional development. Such schemata are useful to evaluate both the participating teachers and the environment and teachers' self-evaluation. They allow, for example, to: **(i)** identify and analyse ideas that were (or were not) given priority during the teleinteractive process; **(ii)** identify a continuity in ideas; **(iii)** classify the types of contribution that appear; **(iv)** verify the regularity of the teachers' participation and, **(v)** use the schemata with the teachers themselves as a tool for a metacognitive evaluation, whether for a macro analysis of the whole course process or the analysis of a specific moment.

The interventions and elements of PCK

The forum was a space for continuous socialisation of practices, allude and integrate other spaces in the virtual environment or their outside world. It is also a space for teachers to immerse themselves in collective discussions (with a response action more flexible in time) that presuppose a security and trust in the professional collectivity of the environment. For the researcher, who has a global and local control over the process, the analysis at the forum allows identifying interactivity points and other links used by the teachers and identifying some components which are potentially positive in the didactic units or communicative spaces in the environment.

The attention to personal reflexive processes and their socialisation along the process - with the necessary personal time - of professional development was a noticeable fact in the work dynamic at the forum. The virtual work dynamic allowed for the teachers to assume their actions critically and to become responsible at collaborative work. It also demanded an open mind and acceptance of the teachers to discuss about the newly posed issues in their virtual collectivity.

As for teaching and learning, the dynamic of virtual work and its strategies (Rodríguez-Ardura & Ryan, 2001) favoured a shared continuous development of professional knowledge (Bairral, 2002). Different professional actions are in continuous and critical movement. In the case of teachers, we have: access to the environment, carrying out tasks, initial positioning with some type of justification, constructive exchange and integration of perspectives. Also, in the case of the researcher, the actions involved in the process: facilitation, commitment and integration of perspectives. In the same way, in the case of the researcher there are different actions involved in the process: facilitation, commitment and integration in the process, differential personal attention (in function of the demand of the teachers), socialisation and attention to a collaboration committed with the teacher.

In terms of PCK, critical teleinteractions are distinct and uneven in their professional development. The teachers detail varied positioning and reflexive reasoning of different orders. For instance, we consider that from the moment teachers are willing to go public with a contribution presented to an initially unknown environment and to accept comments and reflections from what they socialise, there already appears a professionally important action: opening their mind and entertaining new ideas. Even if their contributions are not metacognitive in nature, it can be important for the development and collective production of contributions at more elaborate levels, which is what the proposals interested in the development of the professional knowledge content seek. In this movement of sharing professional meanings and practices, different professional actions (both the teacher's and the researcher's) integrate towards a reconstructive transformation of pedagogical meanings and practice.

With this research, we have shown that analysis of electronic discourse in discussion forums supplies researchers with rich information concerning possible metacognitive development (Santos-Wagner, 1999) of teachers engaged in professional development.

Besides the triangulation of information that comes from other communicative spaces of the formative environment, the construction of three different schemata allowed the researcher to understand and analyse the textual superstructure (van Dijk, 1985) in the discourse community. This process of meta-triangulation through the use of several methods (Meijer, Verloop & Beijaard, 2002) was an important methodological strategy for an accrued validity to our interpreting, confronting and generating the research data and results.

The forum, together with the researcher's diary and the messages exchanged with the teachers, also enabled the researcher to identify factors inherent to the professional daily practice of the teachers that are external to the virtual environment but that influence the virtual interactive process. For instance, when the researcher identified a decrease in the forum participation and got in touch with the teachers, they often claimed they were overloaded with other tasks such as meetings and exam correction.

In the dynamic of virtual work, the researcher plays some important roles, as inquirer and deepener of ideas (Bairral 2003). Just as in the research of Giménez et al. (2001), the continuous follow up and control from the researcher was also important for our work. For instance, in the discussion forums, the researcher diligently attempted to involve other teachers to continue or provide feedback to issues advanced and to deepen the collective analysis. The researcher's monitoring and intervention enable new teacher contributions, with argumentative features, and in turn causes new ideas to be elaborated. Metamorphosis and mobility of the centres are hypertextual characteristics (Lévy, 1983) exemplified in this type of teacher interaction.

It is also important to underscore that beside the advantage of having all communication recorded, the creation of a researcher's diary was invaluable so that information was not lost and so that teachers and the researcher could have access to the text and metacognitive reflections about teachers' contributions. The possibility of uninterrupted communication among teachers, enabled by the virtual environment, was

another methodological element so that the researcher could continually socialise among the teachers his observations about their discourse.

The implications of the virtual environment for the PCK of teachers depends on the discourse established in each communicative space. After analysis of the discussion forum obtained from the contrast among different constructed schemata, the researcher can also carry out a triangulation of the data by referring to other information concerning professional development in other spaces in the environment. For example, we analysed the implications and contributions from spaces such as chats, e-mails, individual or collective development of tasks, self evaluation, and questionnaires to understand teachers' professional development. We have added other information during interviews and recording teachers' classes and teachers' behaviour in the other contexts in which the teachers are involved. Nevertheless, the researcher's diary showed great amounts of information that is available about this type of environment, which implies a considerable amount of work. Also, we think that the organisation of the data could be reduced with the help of technology, so that the researcher can commit most of his or her time to follow the discussions and to get metacognitively involved in them. That is, the problems and technical help could be solved with some other kind of support.

Finally, we would like to emphasize that analyzing interactions that occur through distance learning is not a simple task. In our studies, we have seen that there is not technological support to account for the professional development activity. Professional development programs that use distance learning need to use a variety of strategies to obtain continual information participants' learning. This information should enable researchers to understand better the professional development activity in a broad sense. That is, it should afford opportunities for the interlocutors to reflect critically on their different pedagogical actions and to analyze the implications of new cognitive skills that can emerge in the distant interactive process. In recent studies, we are analyzing implications of different sources (video clips, animations, simulations and Applets) and discursive modalities (written, oral, and imagistic) in teachers' mathematical learning.

NOTES

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¹ For example, Bereiter (1991) describes how elementary school-aged children cooperatively employ a computerized information medium (CSILE) through the use of student-generated questions and annotations. The researchers structured CSILE (Scardemalia & Bereiter, 1996) to promote cooperative interactions in which individuals develop unique ways to elaborate, connect, or otherwise use the features of the system. The system, now called Knowledge Forum, in turn, continues to evolve dynamically through the integration of student-supplied information and questions, affording users the opportunity to consider a variety of approaches and perspectives besides their own and those provided by any given document. Similar to the research reported here, the students constructed knowledge and developed metacognitively. An important difference is that unlike Bereiter (1991) we do not consider the hypertextual routes taken by participants to be fixed. In our environment, teachers can write and discuss any idea about their practice in geometry.

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³ The interactions were numbered successively and the arrows refer for one (or most) of previous idea.

⁴ We define deductive argumentation as the intervention to which the teachers contribute by raising questions (or doubts), which they reason about by adding information and to which they propose possible solutions.

⁵ The words in bold are exemplars from the discussion of a priori codes.

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