E-Portfolio improving learning in mathematics pre-service teacher

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Abstract

This research is focused on dimensions of mathematical thinking among pre-service teachers learning through the use of e-Portfolios. The data came from portfolios created and reconstructed by future mathematics teachers. Their process of reviewing and republishing pages through the Internet was constantly saved and reviewed in turn by the researchers. Seven case studies were conducted. Results stress the importance of the use of ICT by pre-service teachers as an interface to become more reflective about their learning and to improve their knowledge. Besides being a tool to recognize different dimensions (technological, conceptual and communicative) the e-Portfolios were a powerful resource for creating, publicizing ideas, and learning mathematics in different ways. The article also presents some methodological issues.

Keywords

Pre-service mathematics teachers; e-Portfolios; dimensions of learning

I. Introduction

The innovative and challenging use of Information and Communication Technology (ICT) is a claim in mathematics education. Interactions and thinking imply a growth of understanding. Mathematics education researchers have theorized close links between communication and thinking (Sfard, 2008) and between mathematical discourse and collaborative work or social cognition (Martin, Towers and Pirie, 2006; Powell, 2006; Stahl, 2009). One tool that can be used to promote knowledge construction in teacher education within the context of ICT is the electronic portfolio (e-Portfolio).

Historically the use of portfolios was most common in other areas of knowledge, as, for instance, in architecture and arts fields. In mathematics education its use is still scarce. In a Brazilian context, its use is still based on situations with pencil and paper (Mondoni and Lopes, 2009).

Recognizing e-Portfolios as an important vehicle to exchange information and to publicize ideas and concepts, we are presenting results from a study conducted during 2010 with pre-service mathematics teachers at UFRRJ. The research question focused on the implications for mathematical instruction and on dimensions of mathematical thinking. The research is also a way to promote reflection regarding qualitative assessment in mathematics using ICT. The electronic portfolio will be the vehicle for development of writing and developing authorship in the process of knowledge construction. The results highlight the importance of the use of ICT with pre-service teachers (PST) as a new interface for their own learning, a strategy for them to become more reflective about their learning and to improve their knowledge. The use of e-Portfolio could also provide new issues regarding authoring process and mathematical learning with technology.

II. Theoretical framework

Traditionally, the portfolio is used as a tool for assessment and the analysis is only focused on the progress of the concepts from a specific subject. As a new interface the e-Portfolio constitutes another virtual environment for learning and instruction. For instance, the possibility of publication in a digital version allows teachers and students' accessibility and visibility of the creation and progress of knowledge construction using a lot of sources, links and mediating tools. For instance, postings, videos, pictures, images, notes, gadgets, publishing files, etc.

As a virtual space of learning, the e-Portfolio constitutes a hypertextual environment. We agree that mathematical language and mathematical thinking develop simultaneously in social interaction (Sfard, 2008). Working with e-portfolios, the interaction should be more than a simple compilation of artifacts (Brandes and Boskic, 2008) and promote learning as a reflective and continuous, hypertextual process. According to Aido (2003) the portfolio should be a justified selection of activities (essays, surveys, inquiries, tasks etc.) that reflects learning and instruction.

In our practice, the published portfolio (the product) is not as important in itself as the process of constructing and reconstructing it. In this critical reflexive process, pre-service teachers can reflect critically about their professional actions while developing metacognitive thinking. To promote this progress the pre-service teachers were assisted collaboratively by teacher and technical assistance to increase their own portfolio.

Hypertexts are important discursive components in the negotiation and construction of meanings on e-Portfolios. Powell and López (1989) note that text construction necessarily involves authors in ordering both thoughts and feelings about things and about thoughts. For instance, as pre-service teachers (re)write and publish texts (movies, resources etc.), they and their readers (the teacher or their colleagues) review their knowledge to understand and reflect on the meaning of the texts.
In virtual scenarios we recognize learning as a hypertextual process. Hypertextual learning implies 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 meaning universes. In such environments, a hypertext refers to the multiple formats, ways, and channels that one uses to access information as well as to the social-technical processes of information access (Lévy, 1993).

Hypertexts represent a more complex discourse modality. Hypertexts allow for the organization of information in direct content blocks connected through a series of links that enable the user to instantly access target information. Hypertexts and metaphors are useful vehicles to move away from linearity and chronology to new organizational modes that better illustrate students' cognitive processes (Brandes and Boskic, 2008).

In agreement with Sfard (2008), we consider that the hypertextual development of cognitive transformations is the result of two complementary processes: individualization of the collective and the communalization of the individual. According to her, individualization and communalization are reflexively interrelated. Individualization results in personally modified versions of collective activities, whereas some of the individual variations feed back into the collective forms of doing and acquiring permanence, and are carried in space and time from one collective to another.

Assuming learning as a mediated process by immersion and participation in a particular environment of learning supported by different mediating artifacts, we are interested in analyzing the way in which pre-service teachers construct their e-Portfolio and transform them hypertextually. This process takes on an individual moment (when it is being created), as well as a collective phase (when it is published). Although there appear some isolated moments, they are related, as the (individual) creator has in mind the reader who will access his/her e-Portfolio (communalization).

III. Context, data collection and analytical process

Our ongoing research1 is a longitudinal study focused on the implications for mathematical instruction and on dimensions of thinking among high school students (Costa, 2009; Bairral and Costa, 2010) and in teacher education. During the year 2010 we implemented the e-Portfolio for 20 pre-service teachers during a regular course called "Practice of Teaching Mathematics". Besides the contents concerning instruction and learning processes, the subject of the course was focused on development of geometrical thinking. Promoting reflection regarding construction of knowledge in geometry is still a demand in Brazilian pre-service teacher curriculum.

[1] Research granted by Brazilian Foundations (CNPq and Faperj).

For this article we conducted seven case studies[2]. The data came from e-Portfolios and every one was considered as a unit of analysis. Each student continually created and reconstructed his or her portfolio. The process of reviewing and republishing pages through the Internet was continually saved and reviewed by the researchers (teacher and graduate students working on a Master's degree program). For the triangulation process we adopted the following procedures and sources. The period of time of observations is also indicated.

Procedures	Sources	Schedule of observation
1. Access and systematic observation on the e-Portfolios	Tables indicating the emergent aspects and changes	Five times during the semester. The date of observation was previously scheduled.
2. Accessing each portfolio and public self-reflection	Notes	Weekly, during the classes
3. Self-assessment3	Writing on paper and posting on the e-Portfolio	Three times (after first, third and last construction/publishing)

Table 1 – Analytical process summary

To access and register the systematic observation on the portfolios each researcher constructs a table as the following. After their observation indicating the emergent aspects, changes and other issues, they exchange the tables[4].

Student	Version 1	Obs.	Version 2	Obs.	Version n	Obs.	Last version	Final observations
1								
2								
n								

Table 2 – Table from each researcher's systematic observation

The University provided one computer for each student. One graduate student in a Master's degree in Education conducted the orientation process of construction and publishing of the portfolios. As progress on the construction was our focus, we provided for pre-service teachers only the first step for publishing, without ICT details. We spent about two class hours giving them the first

[2] Since in a prior study (Costa, 2009) we observed the amount of work involved in this kind of research, for instance, continuously observing the portfolios changes (capturing screens and writings), we decided to analyze only one in our class, the smallest one. That decision is also an important didactical strategy because we need time to analyze each portfolio together (technical, research and PST people implied) and share ideas for future versions.

[3] PSTs are often invited to write about the process of (re)construction of the portfolio and their influence on their learning. There is no specified format regarding this. They are asked to reflect about future ideas and links, conceptual changes, ways of reasoning, constrains (with ICT or mathematics) etc.

[4] On Figure 2 we illustrate as the table is filled. Sometimes we also add screenshots as examples to show improvements.

information and publishing everyone's portfolio. Since it was free, we used the Google sites. The detailed information and technical support was provided weekly during the process of accessing and commenting the portfolios (Table 1: procedure 2) according to students' demands.

In the next section we are summarizing our results underlining two aspects that we observed in the e-Portfolio regarding the pre-service teachers' learning process (i) as a strategy to recognize different dimensions during the process of creation, and (ii) as a resource to study, publicize ideas and learn mathematics in different ways. As an example we gathered the information and carried out the analysis. We are providing data from each procedure (Table 1).

IV. Results

Since the virtual environment is dynamic, it is difficult to gather all the information, and changes happen constantly, so one of our strategies was the creation of screenshots from the portfolios. Those screenshots were almost daily saved. Since the screenshot generated a picture we also visited each link and saved all the postings and writings in order to observe changes in writing discourse. In the following three pictures we see one example of how we capture and highlight the changes (Table 1, procedure 1).

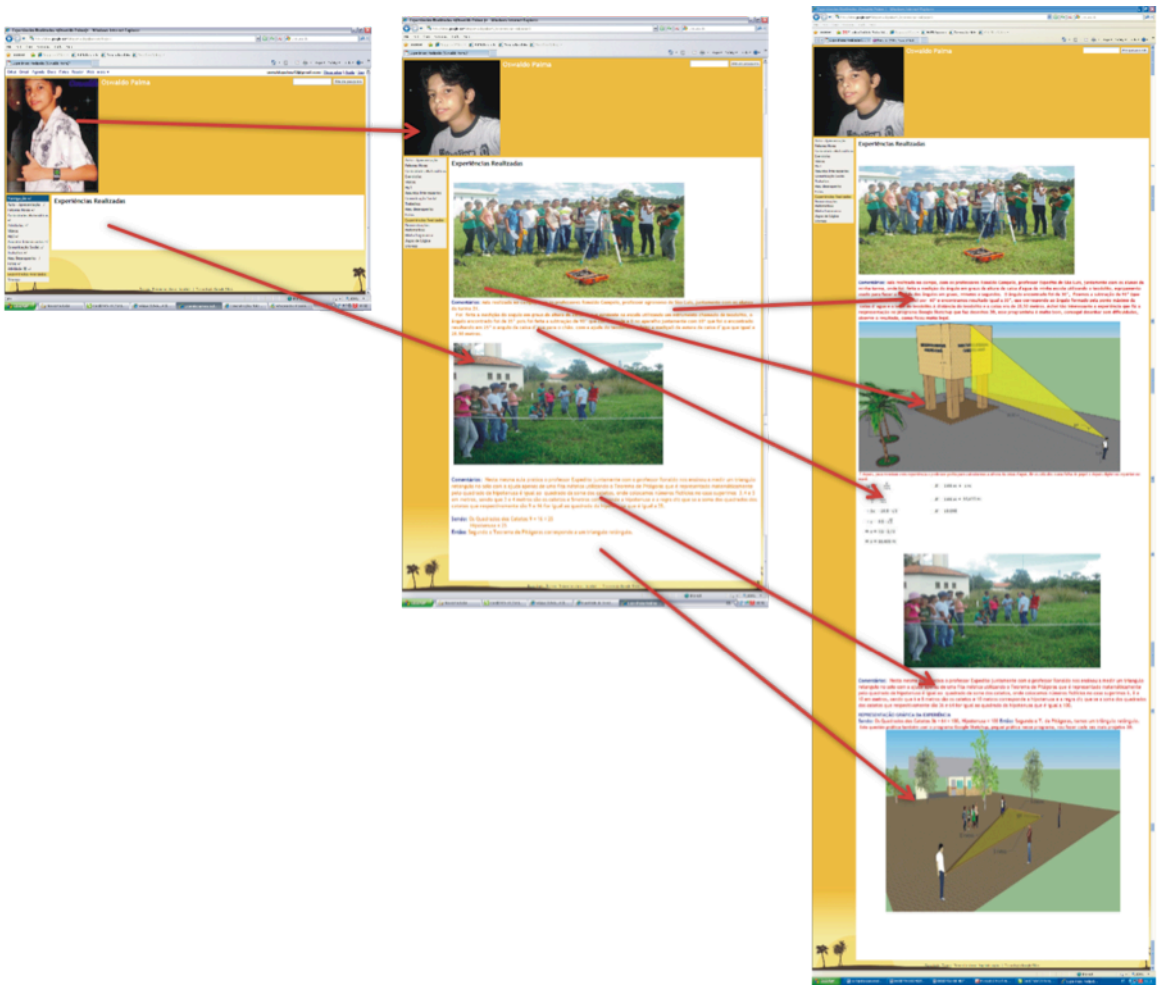


Figure 1. Screenshot from three captured versions. http://sites.google.com/site/oswaldopalma43/

As the arrows indicate, the student changed a previous posted picture, added two new ones, improved his writing and added a gadget. Also, he added pictures as a strategy to explain his way to solve the problem. Using some specific software the student elaborated a geometric representation to make his solution clear.

Since we were interested in improving PST creative thinking we didn't provide a template for the portfolio. Each e-Portfolio had their own format and they weren't compared. Every PST organized links and published information (curiosities, YouTube videos, pictures, etc.) and activities done by them during the course. The only recommendation is that publishing information had to have some significance for him/her. In this hypertextual process of creation and learning, we found three interview dimensions (conceptual, communicative and technological) and observed the continuous motivation and interest of the students regarding mathematical instruction and their own learning process, as we summarize on Table 3.

Dimension	Competences	Evidence
Technological	-Use of different sources	-Added pictures, images, videos, gadgets and postings
	-Increase reasoning process	-Use of software to construct figures
Conceptual	-Use of appropriate concepts and property	-Applied the Pythagorean theorem -Explained the solution for the question
	-Increase mathematical thinking	-Added 3-D representation to enrich the process of resolution
Communicative	-Development of writing	-Changes and improvements during the process of construction
	-Promoting interaction	-Comments on the colleagues' portfolios

Table 3 - Dimensions observed: conceptual, communicative and technological

When used in a conventional way (pencil and paper) the use of portfolio tends to be focused on one specific subject or field. Our analysis shows that e-Portfolio can be a helpful tool to promote, among pre-service teachers, the capacities to integrate different areas (Geometry, Algebra, Psychology, Technology, Language etc.) of curriculum and the emergence of different concepts, thinking and sharing experiences.

Accessing the portfolios we can also see different aspects regarding mathematics thinking and learning (Table 1, procedure 2) in progress. For instance, on the following screenshots we show some aspects that can be observed when PSTs are improving their knowledge regarding the number of platonic polyhedrons.

-Nomination and illustration from each polyhedron

-Introduction of the idea concerning the existence of only 5 regular polyhedrons

-Using the strategy of the sum of internal angles

Figure 3. Screenshot from three captured versions regarding platonic polyhedrons

Looking for aspects on PST learning we also can identify discoveries, constraints and different ways of reasoning. For instance, PST Al posted a reflection about the importance of description in the development of geometrical reasoning.

> "In this lesson, I wrote down a sentence that the teacher said which called my attention: 'The description is very important in learning, mainly in geometry'. Then I asked myself: Why? (…) We have to think before writing, we have to read, to reread, to rewrite until concluding the description. Therefore in the learning process the description becomes an important element through which the teacher provides students' reflections on their knowledge and vision of the world (…)." PST Al (http://sites.google.com/site/profalinecom/aulas/aula-1)

This idea is posted on link Lesson 1 (*Aula 1*) from her portfolio (Figure 4). Her comprehension about the nature of the description and its importance for the learning is clear on her writing. She also gathered one definition from description from a Dictionary, summarized and posted it. On the link Lessons (*Aulas*) she published short reports about lessons. In most of them she used different sources to summon her colleagues for a debate and collective reflection.

Besides conceptual reflection concerning the role of description on cognition the PST adds a picture at the end on the link Lesson 1 as a communicative strategy to motivate the visitors. In the following Figure we can also see her technological improvement organizing the link within different categories (Activities at School/*Atividades na Escola*; Lessons/*Aulas*; Self-reflection/*Auto-crítica*;

Schedule/*Cronograma da Disciplina*; Curiosities and Resources/*Curiosidades e Materiais*), as shown on the following screenshot.

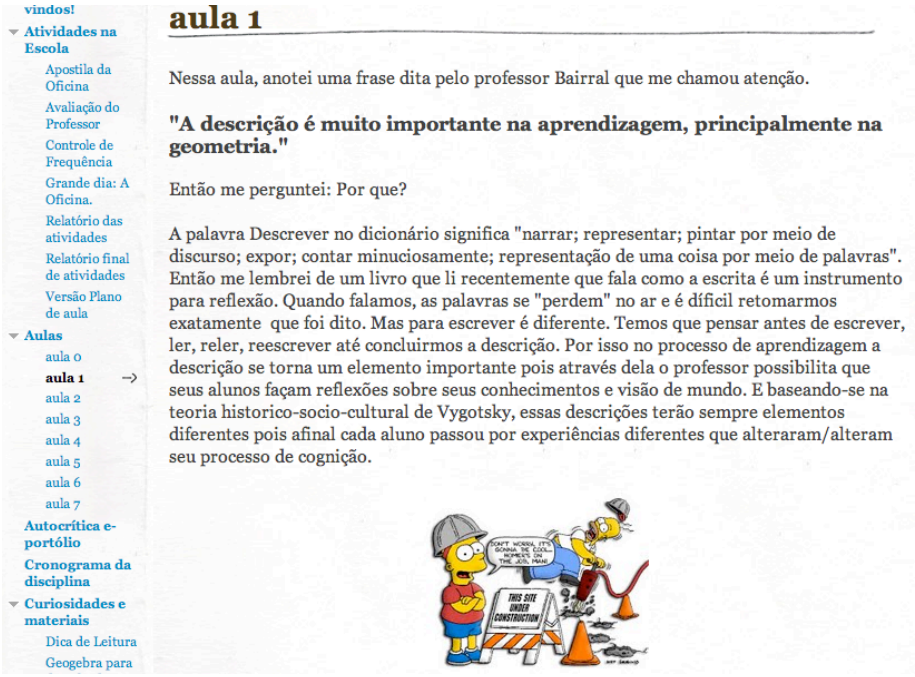


Figure 4. Screenshot from PST An reflecting concerning the role of description on the learning

Writing his first self-assessment (Table 1, procedure 3), PST An reflects about the importance of the e-Portfolio for classes in general and makes explicit some of his plans to improve his portfolio's design.

> "By now the portfolio has been an instrument for investigation of resources and its possible applications in the lessons. I believe that the portfolio has a great potentiality as a complementary resource for classes in general. In version 2, I will do some improvements in terms of a design and information I had in my imagination during this last week" (PST An, self-assessment version 1).

The imagination and reflective thinking regarding the kind of information he will publish (whether influenced or not by his colleagues' portfolios) is visible on PST An's self-assessment. One month later, writing his second self-assessment (see full tipping on link portfolio self-assessment), he appears to feel satisfied with his changes.

> (…) "My current portfolio changed significantly regarding the first version. I already made many improvements in terms of content and 'lay-out'. I really want to improve the interface a little more. I realize that the portfolio has a great potential for the lesson" (…) (PST An, self-assessment, version 2).

Since the process of (re)creation of the e-Portfolio is dynamic and continuously stimulated by the teacher, we can observe his interests and stimulus for new arrangements and changing. His last comment shows how the resource is being apparently powerful in his lessons. The following three

pictures summarize the improvement observed on PST An's learning in two domains: (1) his continuous motivation and interest in mathematical instruction and (2) his creative learning reconstruction of his portfolio.

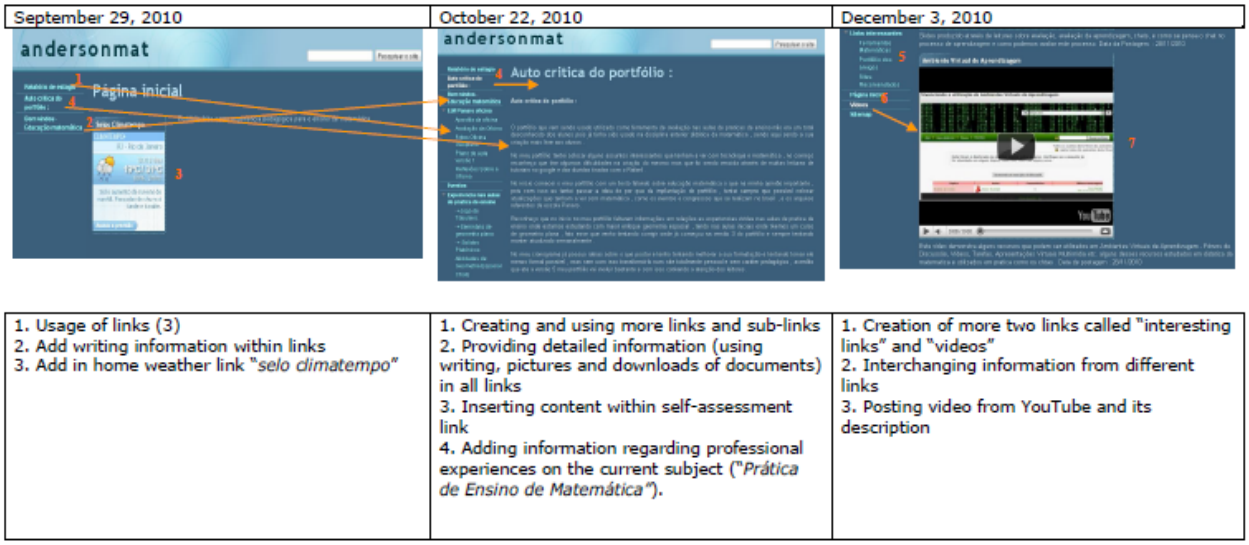


Figure 2. Screenshot from three captured versions (2nd, 3rd and 4th)
http://sites.google.com/site/andersonmat23/

The screenshots show how PST An improves the interface. He changes versions of his e-Portfolios from merely using links to trying to relate information across different links.

Although the process of construction and publicizing portfolios appears as isolated moments, they are interrelated: as the (individual) creator has in mind the reader who will access his/her e-Portfolio (communalization). According to one PST, Tan, this individual process assumes another characteristic: when it is being created, it involves some responsibility and this presented some further difficulty on the creative process. Besides using ICT tools, she had to consider each task in terms of not hurting anyone's rights, as we can see in her self-assessment.

> "What impressed me was working with the tools of informatics the way we worked during the course. Building a website that anyone could access was not a simple task. We had to think each activity so as not to hurt anyone's rights. Besides trying to make the site something that would interest prospective visiting Internet users, so that they would want to visit again later on. (...) Therefore, the creation of the site was something of great responsibility. "

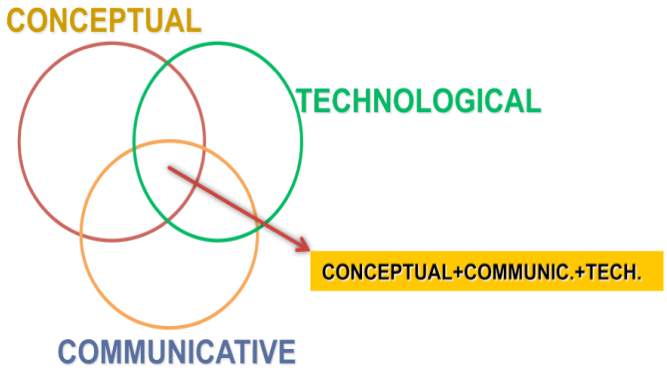
Furthermore, an important way to promote metacognitive thinking emerged from the joint observation done by PSTs and researchers of each portfolio, their sharing of impressions, discoveries and constraints when changing the portfolios. Besides individual responsibility, authorial and creative process, PSTs can reflect critically about their professional knowledge while developing metacognitive thinking (Powell and López, 1989) on the subject.

Finally, our systematic access and analysis of each captured version (Table 1, line 1) of the e-Portfolio show an important pedagogical strategy of researchers and teachers. The strategy involves PSTs in reflection on information published in e-Portfolios and that the information should be more than a simple compilation of artifacts (Brandes and Boskic, 2008).

V. Conclusions

In our research, the e-Portfolio was seen as a systematic meeting point online among pre-service teachers, teachers and the technical support. In this resource PSTs gathered, organized and published their own way. In this section we are presenting issues regarding PST learning as well as methodological ones.

Traditionally, the instruction of mathematics is done through tasks that aim practice in calculus and memorization of formulae applying usual skills or models of reasoning. Using e-Portfolio trainers presents new challenges: it considers mathematical learning involving other dimensions. In our research we observed three of those: conceptual, technological, and communicative, as illustrated in Picture 5.



Picture 5. Interrelated dimensions of mathematical learning

Sometimes we can see aspects of learning in only one set, but our recommendation to teacher education using e-portfolios is to try to improve learning at the intersection of those domains.
Our practice was centered on the PSTs' creativities and potentialities, and providing them with constant stimuli. Although PSTs were always wondering as to format (examples from prior models of portfolios), we feel that teachers and researchers should not interfere during this authorial and creative process. Teachers have to provide technical support and information as far as students ask. Since the use of e-Portfolio implies new ways to deal with the time and creates different expectations on the group, we have seen that the strategy to schedule the dates to access the portfolio is very important.

We agree with Sfard (2008) that discourse permeates and shapes all human activities. The e-Portfolios were an important vehicle to exchange information, change discourses and to publicize ideas, concepts and ways of reasoning. With more experience and further analysis of existing portfolios, pre-service teachers became more nuanced in their organization of their e-Portfolios, reflecting the messages they conveyed (Brandes and Boskic, 2008). Learning with e-Portfolios as a mediating artifact corresponds to a change on discourse. In this process of changing, interactions and collaborative suggestions assumed an important role.

While reconstructing their e-Portfolios pre-service teachers applied technical sources (YouTube videos, pictures, etc.), created different types of activities (reports, curiosities, diaries, games, etc.) and posted information about themselves used by them during the course. This commugnition process (Sfard, 2008) improved by ICT became a useful vehicle to move away from linearity and chronology to new organizational modes that better illustrated students' cognitive processes (Brandes and Boskic, 2008). During this creative and authorial process, we found three dimensions—conceptual, communicative and technological—and observed the continuous motivation and interest of the PSTs regarding mathematical instruction and their own learning process.

The use of e-Portfolios constitutes a propitious scenario for knowledge construction. This knowledge is hypertextually constructed in the conjunction of images, music, videos, writing and other kinds of discursive manifestation. In this process, the communication, the creation and the authorship assume an important role. As mathematics educators we have to develop ways to promote learning when ICT is being integrated in teacher education programs.

We have seen that it is difficult to use the portfolio for more than a compilation of information. On the first or second version PSTs tend to construct portfolios without relating the information publicized into the links or explaining the importance of the available content for their learning. This kind of relationships can be observed rather after the fourth version. Working with e-Portfolio in a short course (or in a limited period of time) as a way to improve analysis in PSTs is still a challenge.

In future research we will analyze the discourse (postings, writings, etc.) and PST learning across the portfolios' links and even among portfolios. Of course, as researchers we are looking for better procedures to capture, for instance, the changes on the screen and in writings, and other forms of manifestation of discourse.

Taking into account the hypertextual dynamic of the e-portfolios and the amount of information posted, we are going to carry our next analysis focusing on: (1) one activity and related resource; (2) one mathematical conceptual doubt that one would clear, and (3) one PST interest to think and develop in order to improve his/her professional practice. Each PST should decide on those three items and inform the teacher.

Since most teachers consider students familiar and motivated with ICT they tend to use it in some homework assignment. This kind of use provides only for an individual and isolated learning process. Students often do the task at home, show the teacher and the learning process is concluded. Working with e-portfolios involves a great amount of time to observe continuously the changes and the recreation process. Even though we have a schedule to see PST portfolios, we recommend that all individuals enrolled in the process (technical staff, researchers, teachers and students) share their portfolios. For us, this is a strategy to keep participants seduced by the use of ICT as a resource to learning. In terms of research, we have seen that case study provides us with an important strategy to analyze the reflective and creative process in depth.

Finally, when working with ICT teachers often try to transfer their understanding of students' learning. We think we have to promote training courses with ICT that place teachers' knowledge at the center of the process, which includes using ICT in a variety of ways. Although students'

learning could be the goal, we would say that working with PST using ICT we might provide them a moment to reflect about their own leaning.

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