CONTINUING PROFESSIONAL DEVELOPMENT AND DIGITAL MEDIA IN MATHEMATICS EDUCATION

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***Abstract**: This paper presents the results of a study in a continuing professional program for mathematics teachers that had as main objective the integration of digital medias in their teaching practices. The program was offered in a distance education modality. The didactic material was designed taking into account cognitive aspects that can transform the digital media into a powerful math learning tool. The analysis of the design of the material, as well the analysis of the learning process, uses as main frameworks the theory of semiotic mediation, the registers of representation theory and the theory of instrumental genesis.*

INTRODUCTION

Studies on mathematics teaching and learning in digital environments have been developed since Papert´s work (the turtle geometry in the 80's). Since then, a considerable development of theories has happened (Gueudet & Trouche, 2010). One important subject focus has been the technology's potential to enhance the cognitive process in mathematics learning (Moreno-Armella, Hegedus & Kaput, 2008).

However, the integration of technologies in the practice of mathematics teachers has been happening very slowly, as reported in different studies. This is because a large proportion of teachers were prepared before the massive presence of digital media in our society. Therefore, it is understandable that they prefer to keep away from practices that make use of digital media. As a result, programs of continuing professional development are necessary to overcome the absence of digital resources in mathematics classrooms.

In this paper we present the results of a research in a continuing professional program for mathematics teachers offered by Mathematics Institute at Federal University of Rio Grande do Sul (UFRGS/Brazil). The "Mathematics, Digital Media and Didactic (MDMD)" is a distance education program that had its first version in the period 2009-2011. Its main objective is to prepare mathematics teachers for using digital media in their classrooms. We will outline the program design and analyze the teaching and learning process in its first course. This course had focus on dynamic geometry software as a math learning tool.

Our research is based upon theories developed to understand the complex process of integrating technologies into teaching practices. We use the theory of semiotic mediation (Bartolini Bussi & Mariotti, 2008) associated with the theory of registers of representation (Duval, 2008) to address the potential of technology for learning mathematics and the theory of instrumental genesis to address the process of technology skills development (Artigue, 2002; Trouche, 2004).

SEMIOTICS REPRESENTATION, DIGITAL MEDIA AND THE LEARNING OF MATHEMATICS

The theory of registers of representation emphasizes the importance of systems of representations in the learning of mathematics (Duval, 2006). Duval makes clear that the systems used in mathematics not only convey concepts and ideas, but they also have operating rules that allow to perform processes that lead to new concepts and ideas – those are the registers of semiotic representation. The concept of transformation highlights the mathematical process that occurs within a register (the treatment) or that occurs between registers (the conversion). The coordination of registers creates mathematical comprehension and enlarges cognitive abilities.

Digital media enlarge the possibilities of registers of representation. Indeed, nowadays there is a number of dynamic representations that can be manipulated directly on the computer screen. Different registers are synchronized - text, graphs, figures, equations and also metaphorical objects – offering different aspects of the mathematical object. This makes the digital tools powerful in the development of cognitive abilities for the learning of mathematics (Moreno-Armella, Hegedus & Kaput, 2008).

However, digital systems of representation might not be enough to ensure the learning of mathematics. The efficient use of digital systems of representation depends on the design of didactic situations in such a way that the students can develop utilization schemes that will convey mathematical ideas (Bartolini Bussi & Mariotti 2008). In a vygotskian perspective the digital systems can be seen as tools to support and develop mental activities.

We also rely upon the theory of instrumentation that explains the dialectic between conceptual and technical work when using a digital artifact (Artigue, 2002; Trouche, 2004). The differentiation between artifact and instrument is clear in this theory: an instrument is a mixed entity that involves an artifact and cognitive schemes of utilization. In this theory, the development of cognitive schemes, which will make the artifact an instrument, is defined as instrumental genesis. On the one hand, this development depends on the subject's actions towards the artifact (the instrumentalization process). On the other hand, it depends on the subject's actions that are provoked by the feedback of the artifact (the instrumentation process).

The interesting expression *toolforthougths*, coined by Clinton and Shaffer (2006), highlights that subjects and artifacts (as digital systems of representation) can interact in an action and reaction process that produces cognitive attitudes towards new knowledge. In this paper we will use the expression *toolforthougths* as synonymous of *instrument*, because it conveys in a clear way the notion of ´tool to think with´. Prior to applying digital media resource as *toolforthougths* in their classrooms, teachers need to experience their own *instrumental genesis*. Also, they need to be supported by professional development programs in new practices in order to think creatively about a curriculum that integrates the digital media. We are going to look at these issues in this paper.

THE DESIGN OF HYPERTEXT WITH INTERACTIVE ANIMATIONS

The program MDMD was designed to provide teachers with an understanding of the potential of digital media, especially software. Particular attention was given to the process that makes an artifact become an instrument. The courses' contents emphasized the mathematics concepts and skills required to use a software and also pedagogical strategies that could be adapted to classrooms.

The design of the didactic material focused on the role of the registers of representation, as well as the utilization schema to be developed in the learning process. Knowing beforehand the potential of the software as tools of semiotic mediation, we prepared activities that required the utilization schemes related to transformations of registers, specially the conversions. For instance, activities using discursive and geometric registers were planned through geometric constructions with GeoGebra. Real variable functions activities that require the conversion from a geometric register to an algebraic one were also prepared with GeoGebra. An interesting conversion from geometric to algebraic registers was proposed with software GrafEq. In this conversion, algebraic relations produce geometric shapes.

The Program predicted a *cascade of instrumental genesis processes* represented in Figure 1. The activities, designed according to the principles of the theory of semiotic mediation, were organized to provoke teachers´ instrumental genesis. The same material could be used by teachers in their classrooms and could help them to promote a similar instrumental genesis process with their students. The cascade idea might be supported by the theory of documentation (Gueudet & Trouche, 2010); the theory shows the important role of the resources used by teachers while preparing a math subject to be taught.

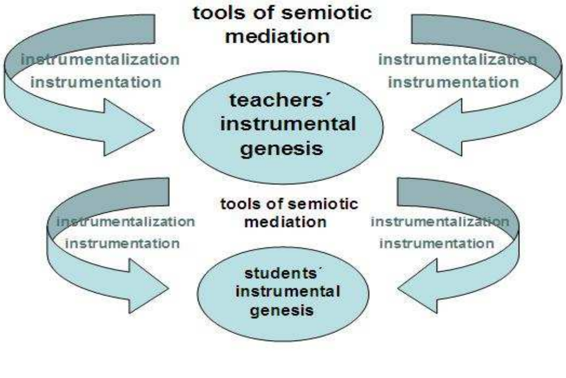

Figure 1: Cascade of instrumental genesis processes

Each course used its own website and focused on a different software. The websites have a similar design in order to make the navigation easier (Figure 2). In the left frame there are modules and each one divided in sub menus: (i) objective - gives the answer to the question ´what we are going to study in this lesson?´; (ii) contents – presents the mathematics contents and the didactic background theories; (iii) activities – brings the activities to be developed; (iv) resources – presents tutorials for the software to be used; (v) complements - suggest additional material to enhance the contents and media used in the module. We will discuss a specific course of the program, Digital Media I, which emphasizes the GeoGebra as a math learning tool. As undergraduate courses in Brazil, even nowadays, still do not prepare teachers for integrating digital media in their teaching (Jover, 2008), the website was designed to provoke the instrumental genesis in dynamic geometry environments. The main purpose was to provoke the utilization schemes for properly explore the dynamic geometry, specially the "drag action" schema.

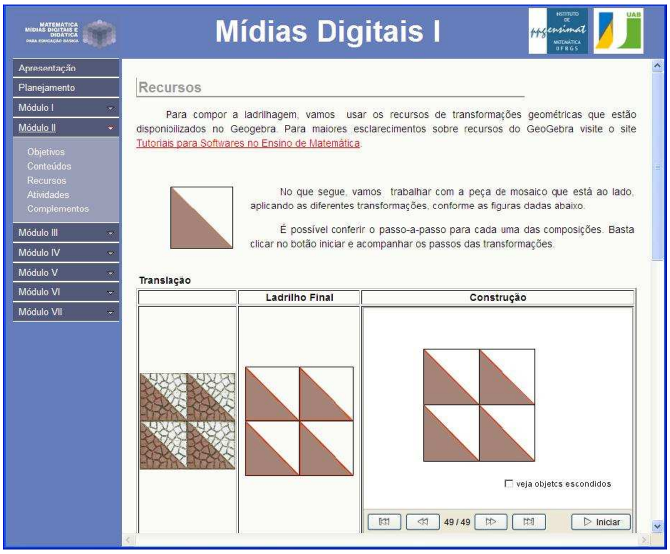

Figure 2: One of the course website interfaces. In the detail, the submenus objective, contents, resources, activities and compliments.

The theme of the module I and II is mosaics and tiling patterns and the module III is about geometric modelling. We are going to observe the instrumental genesis process through the work realized in those three modules. The whole site material can be seen at http://www.ufrgs.br at the link ´Disciplines´.

In module I the teachers are invited to observe different mosaics in their everyday life and produce a similar one with GeoGebra. A simple construction like this is not easy for beginners in dynamic geometry. The site offers interactive animations that explain how to produce mosaics and the construction procedure can be followed step-by-step in the user's learning pace. The module II focuses on the geometric transformations: the task is to produce different tiling patterns using the same mosaic but different transformations (reflection, rotation, translation). As in the mosaic activity, interactive animations are available to help the beginners.

In module III, geometry is explored through modelling. Now the task is to produce a virtual model of an everyday-life mechanism – as a fan, a car piston, a hydraulic jack or a scale. Some virtual models that can be manipulated are available in the submenu *Contents*. Interactive animations and the protocol of construction that will help in the understanding of the construction procedures is presented in the submenu *Resources*.

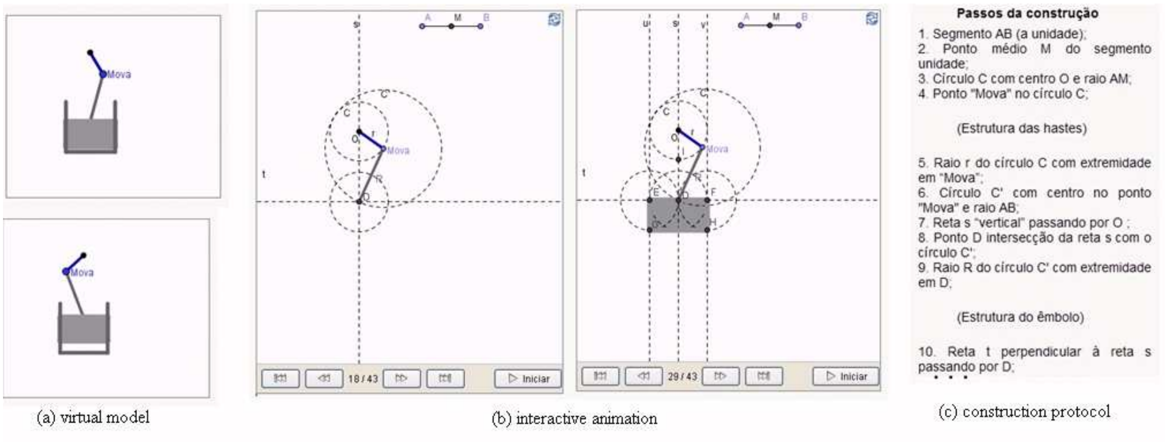

Figure 3: Different registers of the model piston in the website.

Figure 3 illustrates the resources available in module III related to the model “piston”: (a) shows two instances of the virtual model; (b) shows two different moments of the interactive animation of the construction; (c) shows the construction protocol.

The material offers different registers of the model to be learned. The virtual model can be manipulated (the “drag” of the blue point produces the piston movement) and the dynamic geometric register might be enough to proceed with the construction. Otherwise, the user can observe the step-by-step construction using the interactive animation and, at the same time, manipulate the model. If this second geometric register is still not enough to proceed with the construction, the user can read the discursive register.

One of the characteristics of the interactive animations is the navigation bar allowing going back and forth in the geometric construction. If necessary the user can also change the steps speed. Those two features make the interactive animation adaptable to different learning rhythms, which is an important aspect to be considered in the process of *instrumental genesis*. The teachers learned to use GeoGebra in the distance education program MDMD using those resources which were organized in a website.

A TEACHER LEARNING TO USE THE SOFTWARE GEOGEBRA

One hundred and eighty teachers attended the course and were accompanied by a professor and seven tutors. Teachers were distributed in seven cities in the state of Rio Grande do Sul, forming a group between 15 and 30 participants. A tutor, under the supervision of the professor, supported each group. Part of the material used was the website “Midias I” presented in the last section. Guidelines for the activity to be performed were posted weekly in the virtual environment (Moodle). The teachers published their production in a Moodle Database consisting of a GeoGebra file and a text about the difficulties and the progress during the week. The interactions between groups and tutors happened in a Moodle Forum.

As most teachers had no knowledge of dynamic geometry software, it was interesting to observe their instrumental genesis process. In what follows we will analyze the process experienced by one teacher. Through his production in the three first modules of the course we will bring evidences of the instrumentation and instrumentalization processes that were experienced by the teacher. The analysis uses the material posted weekly by the teacher on Moodle. In his first attempts to produce the mosaic activity, proposed in module I, he says:

> I did not know the software, so I had great difficulty .... I made several attempts because I was not having success to move the vertices of the mosaic without any deformation in shape.... I felt that it is needed a specific training with GeoGebra, so that we can explore constructions and then get the desired results.

When the teacher talks about the need of specific training to explore the software to accomplish the construction, he stresses the importance of recognizing the potential of the software (the instrumentalization process). When he refers to the need of practice with the software to obtain a figure in dynamic geometry, one can see a manifestation towards the development of utilization scheme (the instrumentation process). The tutor´s comment shows that the teacher is still developing the utilization schemes:

> I realized that you explored the software quite a lot and you've already done a nice job ... still there is a problem with the construction related to the figure stability ... but this is common to most of those who are dealing for the first time with dynamic geometry... congratulations for the many construction attempts.

It was observed that the interactive animations of mosaics, available in the website, had an important role in the awareness of the two aspects of the instrumental genesis. The mosaic activity provoked an evolution of attitudes: in the beginning the teacher talks about things he doesn’t know and difficulties with GeoGebra. He explores the software menus and makes many attempts of construction – we would say that he is developing the utilization schemes that will transform the artifact into an instrument.

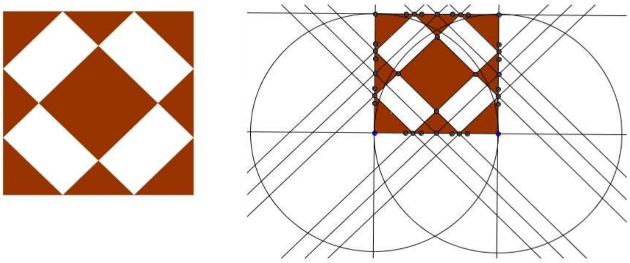

Fig 4: The mosaic produced by the teacher

Figure 4 shows his final mosaic and the geometric procedure. The square, made with perpendicular lines and compass, is a dynamic figure; for decoration he used several times the menu `middle point` instead of the efficient menu of transformations available in GeoGebra – after constructing the first white rectangle, the others can be done through rotation. The teacher´s action indicates an instrumentation process in progress.

In the tiling pattern activity of module II, it was observed that the teacher did not make so many attempts as before. He was quite confident to produce a tilling pattern in dynamic geometry. Figure 5 indicates: a) the tiling pattern produced; b) the construction procedure; c) the basic elements of the pattern. At the end of the activity the teacher says:

> As mentioned in the previous task, I did not know the software ... It was still very hard to carry out the new activity ... For reaching to the end of the task I spent several hours in front of GeoGebra... I am very concerned about the time that will be necessary to perform the next tasks .... I need to learn how to get the desired result faster ... I did my best at this moment.

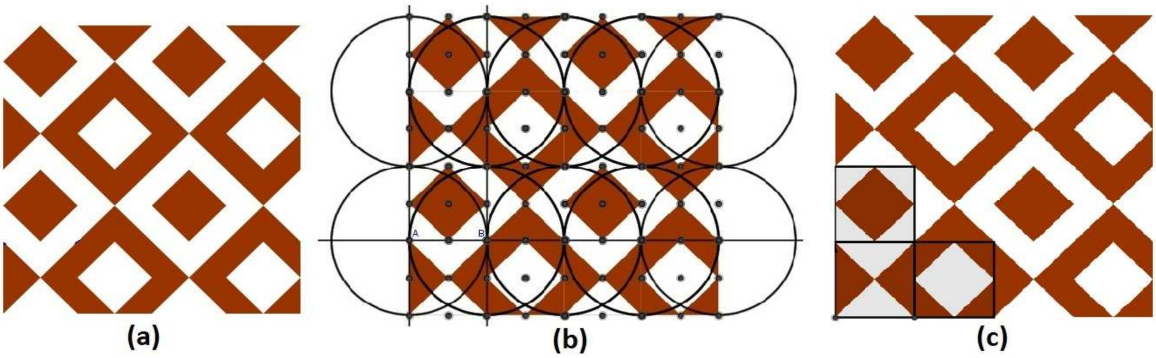

Figure 5: The tiling pattern produced by the teacher

The teacher advanced in his instrumentation process – the figure was made stable under "dragging" without the need of many attempts. However, the utilization schemes related to geometric transformations are still quite incipient even though this was the utilization schema to be developed through the activity. The central reflection transformation was the only one present in the construction protocol and it was applied just to points. The tutor´s comment is:

> As I have mentioned, you already have understood the spirit of dynamic geometry. In the construction of the tilling pattern I noticed the frequent use of the reflections which is very interesting. I let you the invitation for explore other geometric transformations in the task that is coming

The construction procedure illustrated in figure 5b still shows several circles, lines and segments middle points - the construction has about 250 steps. In fact he “spent several hours in front of GeoGebra” to accomplish the task and he still was not using GeoGebra as a powerful *toolforthougths*. He did not pay attention to the basic shapes which are highlighted in Figure 5c. With those shapes and using the geometric transformations (rotation, translation, reflection) it would be possible “to get the desired result faster”, a comment made by the teacher himself.

In the modelling activity of module III, the teacher produced a virtual blind window (Figure 6). The construction required more mastery of the GeoGebra menus. To obtain the `open-close´ virtual movement it was used a point on a circle arc and the corresponding radius was the initial segment of one of the blue parallelograms. The reflection transformation was used in different moments and the translation transformation was used to produce a second copy of the articulated blind window. In this third activity the teacher reveals a progressive recognition of the GeoGebra resources and also shows more confidence with the schemes of utilization.

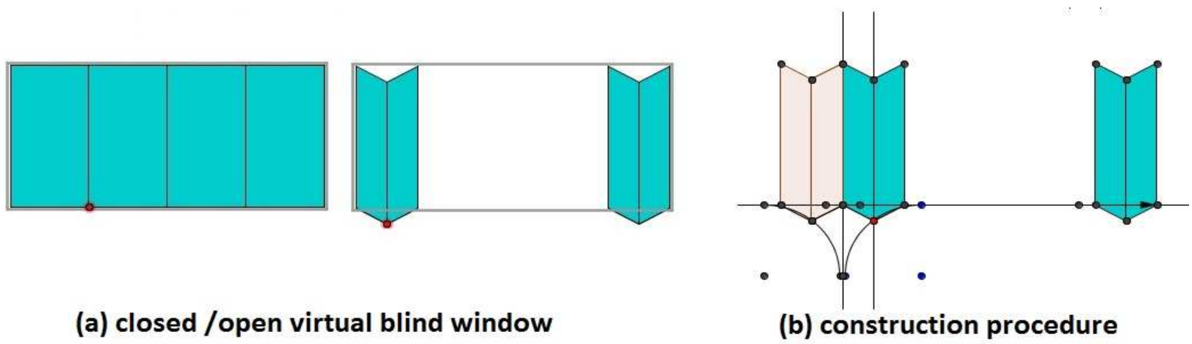

Figure 6: The geometric modelling activity of the teacher

The teacher´s production and his interactions with the tutor showed us that simple activities can be a source of difficulty for those who are starting a process of instrumental genesis. Artigue (2002) points out that the instrumental genesis involves the interweaving of mathematical knowledge and abilities to use the software features. In fact, it was observed that some of the teacher´s difficulties were related with the ability of using GeoGebra features, but he also had difficulties with the geometry knowledge required in the activities. Similarly we observed that the processes of instrumentalization and instrumentation, in the whole group, happened completely intertwined with the geometry content. For instance, it took time for teachers to feel confident to use the geometric transformation menu and the main reason was the lack of knowledge, since geometric transformation is not a school subject in Brazil.

CONCLUSIONS

The analysis of the production of one of the teachers following the Program MMDD shows that the *instrumental genesis* is a complex process. As a general remark we would say that the process depends on many experiences with the artifact so that it becomes a toolfortoughts. As a whole group, teachers did many experiments with GeoGebra. After two months, they carried out teaching experiments with GeoGebra in their classrooms, as part of the course activities. Even though teachers had experienced their instrumental genesis (in fact, the instrumental genesis is always a process in progress), the use of GeoGebra that they did with their students was still quite modest. But even so, they spoke enthusiastically about the new teaching experience. One teacher said that "in the first meeting my students explored the GeoGebra tools... then they started the construction of polygons that do not deform, with motivation, interest and cooperation... they were very excited"; another one said that "the activities carried out with my students were special... I felt satisfaction and delight of the students with their geometric constructions." The teachers´ experiments were not enough to evidence a cascade of instrumental genesis processes.

We might say that for the happening of the *cascade*, a new perspective about the teaching and learning of mathematics must be also envisioned by teachers during their instrumentalization and instrumentation processes. Besides attention to the instrumental genesis process, professional development programs also need to pay attention to what could be called the genesis of a digital pedagogy. The teachers´ experiments with their students showed us that to think creatively about a school curriculum that integrates *toolfortoughts* is not an easy task.

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