MATHEMATICS TEACHERS' INSTRUMENTAL GENESIS OF TECHNOLOGICAL MATERIALS

Paula Teixeira

Ag. Escolas João de Barros – UIED

teixeirapca@gmail.com

José Manuel Matos

Faculdade de Ciências e Tecnologia da UNL – UIED

jmm@fct.unl.pt

António Domingos

Faculdade de Ciências e Tecnologia da UNL – UIED

amdd@fct.unl.pt

Using the paradigm of activity theory, the central problem of this paper1 is the characterization of the processes through which teachers replicate, adapt, and improvise tasks of textbooks with use of technological resources (CD- ROMs and web portals). In other words, we seek to identify teachers' use of schemas in actions mediated by these technological elements. Two of us accompanied Portuguese secondary mathematics teachers in the assessment of learning tasks involving the use of new technological resources and the analysis of feedback of teaching performance after implementation in the classroom. This feedback was obtained from their peers, trainers and teachers' reflection on the actions in classes and occurred during the sessions of the training activities. The study shows that teachers plan coordinated tasks that integrate technology resources and apply them in classes adjusting them to the technological environment of their schools. However, some difficulties in interpreting feedback are revealed.

Keywords: Technological resources, learning tasks, instrumental genesis

INTRODUCTION

Since the 2000s graphing calculators became mandatory in Portuguese grades 10th-12th and gradually textbooks for all grades started to include several technological resources (CD-ROMs; web portals; applets built in dynamic geometry programs; programs in flash). To investigate what teachers do with these new curricular resources matters to the understanding of their professional development. This paper analyses how these curricular materials are incorporated into teachers didactical work.

FRAMEWORK

Human activity is mediated by cultural artifacts, which are culturally, historically and socially produced and reproduced, by means of complex and multidimensional relationships (Engeström, 1999). Artifacts have possibilities for action that the user may or may not use. We are concerned with the ways in which teachers appropriate these artifacts, or, following Drijvers and Trouche's

[1] This paper is supported by FCT - Foundation for Science and Technology (Project "Promoting Success in Mathematics" - PTDC/CPE-CED/121774/2010).

terminology (2008), how they become instruments. Instrumental genesis, therefore, is the progressive construction of schemas of use for an artifact by an actor for a given purpose, which was adapted to the study of teaching and learning mathematics by Artigue (2002), Ruthven (2002), particularly in technology-mediated learning.

Drijvers and Trouche (2008) distinguished two processes:

1) instrumentation, that relates to the management of the artifact when the student is initially confronted with the constraints and potentialities of the artifact that permanently condition his or her actions in order to solve a given problem — for example, turn on a calculator, adjust the contrast of a computer screen, which they call usage schemas;

2) and instrumentalisation, oriented to perform specific tasks, and during which students personalize the artifact in ways that serve his or her purpose — for example, to study the limit of a function with the computer, create didactical exploration scenarios, which they call instrumented action schemas.

Drijvers and Trouche (2008) are concerned with students' appropriation of artifacts. In this paper we will extend their categories also to teachers. In the context of the ways in which teachers appropriate electronic materials for use in their classes, instrumental genesis is sometimes termed documentational genesis following Gueudet and Trouche (2012). In summary, and on a more technical tone, this study focuses on what teachers do with these new technological materials, specifically, how do teachers' instrumental geneses of technological materials occur?

DATA COLLECTION

In three in-service training workshops during the years 2009 and 2011 (totaling 95 sessions) led by two of us, teachers analyzed the technological materials (CD-ROMs; web portals; applets built in dynamic geometry programs; programs in flash) that came with Portuguese mathematics textbooks from six different publishers. Voluntarily, 63 teachers from 24 basic and secondary schools participated in the workshops (table 1).

Table 1. Participant teachers per workshop.

Workshop A 2009	Workshop B 2009	Workshop C 2011	Total
21	22	20	63

These training workshops followed three guidelines (Teixeira, 2015):

Training: workshops were intended as training opportunities.

Action: they were intended as starting points for the work of teachers with their students.

Reflection: these curricular activities will privilege the opportunity to reflect and improve didactical work.

Collected data included oral and written productions of teachers required during the workshops together with written accounts of the sessions produced by the researchers. Special attention was paid to feedback, which is defined by Hattie and Timperley (2007) as information provided to a student by an agent (e.g., a teacher, a colleague, a book, curriculum materials, by itself, an experience) about aspects of their learning, their performance, or their understanding. They argue that feedbacks are one of the most powerful influences on learning and achievement. For these authors, effective feedback may reduce the gap between current performance and performance towards a goal or objective. During our workshops, participant teachers were required to provide feedback to each other.

Data were collected in three different occasions: 1) during the analysis of the proposals contained in the technological materials, 2) during teachers activity preparing tasks from textbooks or the materials, and 3) after its actual application in classroom. Particular attention was paid to accounts of the activities developed by students, and the reflections on the teachers' own performance.

COPING WITH INSTRUMENTATION

Usage schemas that occur in the instrumentation process arose from teachers' analyses of the strengths and limitations of the resources per se, before any conjecture about their relevance to the national program or their usage in class.

Some teachers, especially in the first two workshops only produced this kind of schemas. For example, when asked to describe the technological resources from a textbook for 9th grade, one group of teachers simply listed the contents (index) of the CD-ROM:

> Programmatic contents of the 9th grade, suitable to the current program; Didactic approaches: Introductory videos for all content; Interactive explanation; Interactive exercises; Tests at the end of each chapter; Global test. (Group 2, Workshop A)

This usage does not imply a teaching practice, but just an observation resulting from the first contact with the materials.

INSTRUMENTALIZATION AND DIDACTICAL EXPLORATION SCENARIOS

Instrumented action schemas that occur in the instrumentalization process go further. They result from the analysis of the didactical strengths and limitations of the technological resources, and are imbued with actions centered on their use in class. Here, teachers show how they can build didactical exploration scenarios adapted to the prescribed curriculum, taking into account the resources available in their schools or the characteristics of students in their classes.

These schemas were gradually built by some participants. The following is an example of an instrumented action scheme. The teacher summarizes the actions developed with the technological resources, explains how to overcome school limitations, and hints at several didactical exploration scenarios.

One group, for example, reflected on the didactical exploration scenario orchestrated and suggested how future uses of the materials should be conducted. The intention was to make 11th grade students listen to CD's oral presentations of mathematical content and things did not work as expected.

> As the colleague [teacher advisor] completed the first phase of the lesson, students expressed desire to revisit the CD because they did not understand anything. They were told they could handle the CD at will. Some students individually headed to the desk of the teacher, where the computer was located, and listen the CD [oral presentations] again. They became frustrated as they "could not understand anything".
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> The teachers tried to calm down the students by encouraging them to focus on the presentation of the video, but once the work sheet was distributed, they literally panicked. Their stress was obvious. They could not even use the simple rule of three to convert degrees to radians. (…)

> This reaction from students was extremely surprising to us. (…)
>
> We met in the back of the room and decided to proceed with the next topic, the representation of an oriented angle, to check if they would understand it better. After viewing the presentation of the CD, students were able to answer correctly to their worksheet. But once we started watching them more closely they expressed concern about the previous content. So we decided that it would be better for one of us to present under the definition of radian and the rule of for three simple conversion from degrees to radians independently of the CD. (Group 10, Workshop A)

The limitations of the technological materials were not foreseen by the teachers and became apparent as they were put to use in class. Feedback from fellow teachers during the workshop was instrumental in highlighting these shortcomings.

In another example, teachers question the limitations of the materials and try to overcome them with insightful didactical exploration scenarios:

> As the materials do not present any interactive task, I will use the CD [of publisher B] - Mathematics 9 years to analyze student learning and the educational gains with this type of resource for a math class. For further study of this technological resource in student learning, I want to examine the work of a group of three students who will study some topics of the CD in special extra-curricular lessons and that will present the concepts in a [regular] mathematics class.
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> The CD has some interactive videos and activities that will be explored with and by the students in units "Geometric solids. Areas and volumes" and "Circumference and polygons. Rotations". (Group 10, Workshop C)

This group also reflected upon the strengths and limitations of technological materials:

> The use of CD-ROM benefits student learning, when the presentation of concepts requires a visual support. However, the contents of the CD have proved insufficient whenever it was necessary to apply these concepts, since students were unable to solve the exercises, either on the CD or on the textbook without my support. Only displaying the CD has been clearly insufficient in obtaining any sort of learning. (Group 10, Workshop C)

Examples of a more reflected nature were also found:

> In addition to the manual, I usually use the web site [of the publisher] to view animations related to several content and some interactive applications. While existing animations are sort of a show-off of the site, I usually use them to introduce the topics and then discuss in large group.
>
> I also have access to the eBook, where I can view the manual in electronic format, and flip through the book, looking for resources in the different pages. The projection of the manual [in class] is useful because I can use graphics or pictures to explain something related to what the students should notice and explain them how to solve the exercises.
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> To work, for example, with dynamic geometry software, there are some laptops that can be booked in the school, but sometimes they not in good condition. Alternatively, I ask students to bring their own laptops. (Group 1, Workshop C)

THE COMPLEXITY OF DIDACTICAL EXPLORATION SCENARIOS

As we went through the ways in which teachers adapted the materials, we observed distinct ways in which instrumentalization was conducted by the participants. To frame these differences we used Brown's three types of interaction between teachers and curriculum materials (2009): 1) offloading, the teacher just copies the proposed curriculum materials; 2) adapting, the teacher follows the suggestions in the course material, but adapts them to his or her context and preferences; 3) improvising, the teacher does not conform the suggestions made by the curriculum materials and follows his or her own ideas.

Table 2 summarizes the distinct ways in which instrumentalization was conducted by several groups of teachers using Brown's types of interaction in each workshop.

Table 2: Types of interaction between groups of teachers and curriculum materials by workshop.

	Workshop A	Workshop B	Workshop C	Total
Offloading	6	11	7	24
Adapting	5	0	2	7
Improvising	0	0	5	5
Total	11	11	14	36

Some teachers developed limited instrumented action schemes and their reflections about the didactical exploitation scenarios were essentially descriptive of the actions developed in the classroom rather than reflective teaching experiences. In general many teachers chose a task from the textbook or from the technological resource and only in a few cases adapted or improvised a task.

This was particularly visible in the first two workshops when teachers' experience with this kind of materials was limited. In the third workshop the two monitors decided to stimulate teachers to be more creative about their exploration scenarios resulting in a larger incidence of teachers' autonomous productions.

CONCLUSION

The in-service sessions were fundamental in facilitating the instrumental geneses, namely: the technological resources studied were made flexible by some teachers and thus fostered different educational choices; some teachers developed didactical exploration scenarios to support their practice; and considered the instrumental orchestrations conditions of their schools and the characteristics of students in their classes; teachers shared with peers accounts of this didactical experimentation. Therefore, the training workshops were facilitating the creation of conditions for teachers to transform the artefacts into documents.

The contents of technological resources, their format, the characteristics of students, the prescribed curriculum and schools' technological facilities (in particular, the number of computers per student and the distribution of the resources in the class) are considered in the teachers' instrumented action schemas.

We did not observe a sharp distinction between the two processes of instrumental geneses (instrumentation and instrumentalization) proposed by Drijvers and Trouche (2008). Our data supports the idea that they occur simultaneously. Teachers appropriate the resources and evaluate their constraints and potentials, and at the same time integrate them in specific didactic settings within the context of their school. The transformations of the action of the artifact towards the teacher and towards the action of the teacher in relation to the artifact are complete; they place the two processes of instrumental geneses.

This process is not identical for all teachers. The productions involving both usage schemas and instrumented action schemas show that teachers have developed particular schemas that allowed them to use the transformation of a technological artifact into an instrument. Some teachers developed limited instrumented action schemas. Some reflections about the didactical exploration scenarios in practice were essentially descriptive of the actions developed in the classroom rather than reflective teaching experiences.

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