Use of Graph2Go in M-Learning: A View from the Pedagogical Model

Silvia Batista[1], Patricia Behar[2], and Liliana Passerino[2]

[1] Instituto Federal Fluminense Campus Campos-Centro, Rio de Janeiro, Brazil
[2] Postgraduate Program in Computer Science in Education - Universidade Federal do Rio Grande do Sul, Brazil
{silviac@iff.edu.br, patricia.behar@ufrgs.br, liliana@cinted.ufrgs.br}

Abstract. Characteristics such as interactivity, mobility, reaching a higher number of people, learning in real contexts, among others, are considered advantages of using mobile devices in education. M-learning (mobile learning) can favor learning, not only in distance learning, but also in face to face and blended learning. This paper particularly focuses on mathematical learning, considering it can benefit from m-learning potential in several educational modalities. However, this requires structured actions and, in this sense, development of pedagogical models is important. Such models serve as base for the knowledge building process through organized actions, with defined objectives and established strategies to reach them. Within this context, this paper presents a pedagogical model that was built and applied in a pilot study for mathematical learning using Graph2Go in college students.

Keywords: M-learning, Mathematics, Pedagogical Models, Graph2Go.

1 Introduction

Popularization of mobile devices and wireless Internet access networks has contributed to changes in social practices and to how information is produced and accessed. In this society, which can be understood as the Mobile Communication Society, time and space are the aspects more directly expressing such social change [1].

Within this context, wireless mobile technologies have also raised interest in educational terms. M-learning (mobile learning) is a field that comprehends wireless technologies and mobile computing to enable learning to occur at any time and place, maximizing the student's freedom [2]. M-learning is not only a matter of learning or mobility, but a totally different concept, which is part of a new conception of mobility of a connected society [3].

Several studies have been published on m-learning, such as those related to learning environments for mobile devices [4, 5, 6] and those aiming at the development of didactical materials [7, 8, 9].

In particular, studies have tried to analyze how m-learning can be useful to the teaching and learning process of Mathematics [10, 11, 12]. In general, the studies above indicate several advantages of using mobile devices in mathematical learning,

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such as: i) dynamic visualization and investigation of mathematical facts; ii) different forms of approaching concepts (for example, through videos, working on visual approaches); iii) autonomy in the study of mathematical themes; iv) learning in real situations. Applications for mobile devices have been developed, specifically for Mathematics, such as those designed by the Math4Mobile project.[1] Among these applications is Graph2Go, which allows establishing connections between graphic and algebraic representation for a given set of functions through dynamic changes.

Development of such applications is essential, but it is also necessary to organize forms of applying them in varied educational modalities (face to face, blended and distance learning). In this sense, development and analysis of pedagogical models for this purpose are important. Such models allow organizing pedagogical practices, making them more objective. Based on a pedagogical model, actions can be structured with defined objectives and established strategies to reach them.

Thus, this paper presents a pedagogical model built and applied in a face to face pilot study, using Graph2Go in an m-learning experiment with college students. Section 2 defines what is understood here as pedagogical model, stressing its importance. Section 3 discusses the field of m-learning application in several educational modalities, particularly focusing on mathematical learning. Section 4 describes the pilot study and the pedagogical model applied in its development. Section 5 presents analysis of the pilot study using data obtained from observation and a questionnaire. Finally, section 6 brings some considerations on the present paper.

2 Pedagogical Models

A model is a shared mental representation of a set of relations defining a phenomenon, aiming at a better understanding of it [13]. The concept of model is the foundation for scientific activity, enabling comparison, simulation and understanding of phenomena. In education, such concept has been wrongly considered a synonym for learning theory or teaching methodology. Although a pedagogical model can be based on one or more learning theories, they are generally "reinterpretations" of such theories, based on individual conceptions by teachers [13]. A pedagogical model is "a system of theoretical premises that represent, explain and guide the way the curriculum is approached and that is consolidated in the pedagogical practices and in the interactions professor-student-object of knowledge" [13], p. 4. According to Dabbagh [14], pedagogical models are cognitive models or theoretical constructions derived from models of knowledge acquisition or conception about cognition and knowledge, which in turn are the base for learning theories.

Figure 1 shows the structure of a pedagogical model, based by one (or possibly more than one) learning theory [15]. According to Behar [15], p. 25, a model is composed by a pedagogical architecture (PA) and strategies for its application. PA is the main structure of a model, in which organizational aspects, study content or object, methodological and technological aspects are included.

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[1] Math4Mobile is a project of the Institute for Alternatives in Education that operates within the Faculty of Education at the University of Haifa, Israel (http://www.math4mobile.com/).

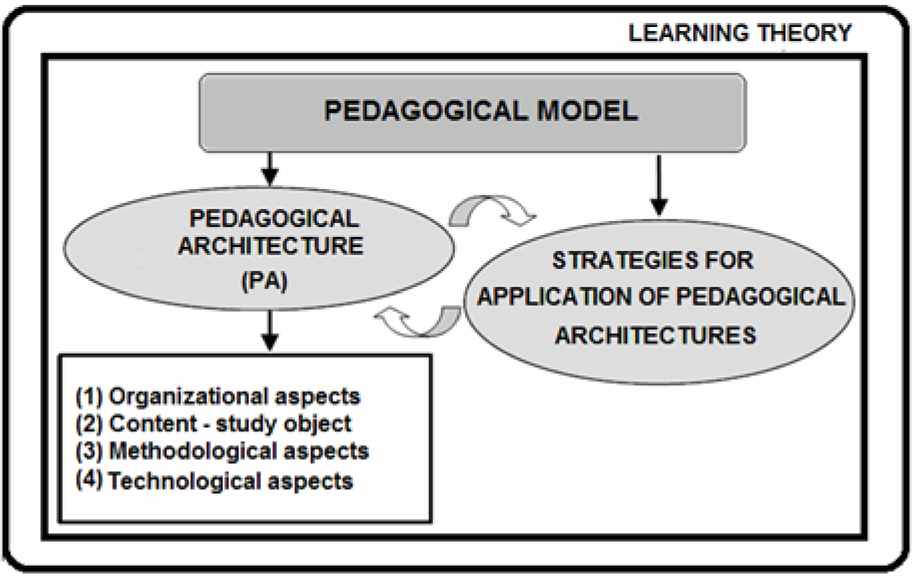

Fig. 1. Structure of a pedagogical model. Source: Behar [15] - p. 25 - adapted with permission from the author.

Putting a PA into practice requires strategies. They are dependant on the real application context and are influenced by several variables that permeate the educational process. Strategies for PA application are the dynamics of a pedagogical model [15]. They are didactical actions focused on articulation and adaptation of a PA into a given context.

Therefore, an application strategy is how the teacher will put PA into practice, already adapted to its reality according to the adopted learning theory [15].

Although the focus discussed by Behar [15] is distance learning, and the model elements are explained from the model itself, it is possible to widen the focus, analyzing them in general terms. In the present study, PA elements were adapted to meet all educational modalities:

- Organizational aspects: comprehend the basis of a pedagogical planning/proposal and include the purposes of the teaching and learning process, organization of time and space and expectations relative to the participant's interaction;
- Aspects regarding study content or object: include didactical materials to be used (texts, booklets, didactical resources, either digital or not);
- Methodological aspects: include activities, interaction/communication forms, evaluation procedures and organization of such elements into a didactical sequence that favors learning;
- Technological aspects: refer to the technological support structure to be used in activities (for example, selection of virtual learning environments, communication tools, inclusion of mobile devices, among others).

Such aspects should not be considered separately, since they form a whole in which a decision about an aspect influences the others. In addition, it is important to consider that the same PA can be applied differently, depending on the strategies used. Application strategies make PA individualized, as they depend on the actors' personal variables.

Development of pedagogical models allows confluence of aspects related to content and organizational, methodological and technological elements, in favor of pedagogical actions with more defined purposes. Pedagogical actions with a better foundation, clear objectives and organized means of achieving them can enable a more adequate use of resources, more coherence with the real context and reduction in unpredictable situations.

This study defends the idea that mobile devices can favor not only distance learning, but also face to face and blended learning. In this sense, pedagogical models including use of these devices can be important in the structuring of activities to be promoted in several modalities. Sections 3 and 4 deal with these respective issues.

3 M-Learning and Mathematics: Educational Modalities

Several studies associated m-learning with e-learning. Quinn [16] states that m-learning is e-learning[2] developed by mobile devices. In agreement with that, Georgiev et al. [17] claim that m-learning can be understood as a new stage in distance learning and e-learning. Wains and Mahmood [3] also state that m-learning aims at meeting some aspects that still impair e-learning, such as lack of infrastructure of Internet access in developing countries and the issue of student mobility.

However, some studies have associated m-learning with face to face and blended learning as well [11, 12, 18, 19]. According to Khaddage and Lattemann [18], it is possible to use mobile devices within the classroom context, favoring aspects such as accessibility, collaboration and flexibility. To Zeiller [19], blended learning can use both Web resources and mobile devices in the communication between students and teachers and in collaborative work.

Thus, association of m-learning with e-learning no longer reproduces the real context. Considering that research has indicated that m-learning potentiality can also collaborate in face to face and blended learning, this study proposes a wider mapping (Figure 2). In that figure, two-way arrows between m-learning and educational modalities indicate there is benefit in both senses. Studies involving m-learning collaborate to the development of this area, either by identification of new application forms, limitations and advantages, or by increase and enhancement of resources.

Within the context of Figure 2, educational modalities are defined as: i) *Face to Face Learning* - modality in which teacher and students are physically present at the same place, at a preestablished time, to perform pedagogical activities; ii) *Distance Learning* - modality "[...] in which didactical-pedagogical mediation in teaching and learning processes takes place with use of information and communication means and technologies, with students and teachers developing educational activities at varied places or times" [20], p.1; iii) *Blended Learning* - modality that aims at combining two educational modalities – face to face and blended learning – into one, supported by digital technologies.

[2] Form of distance learning based on computer and the Internet.

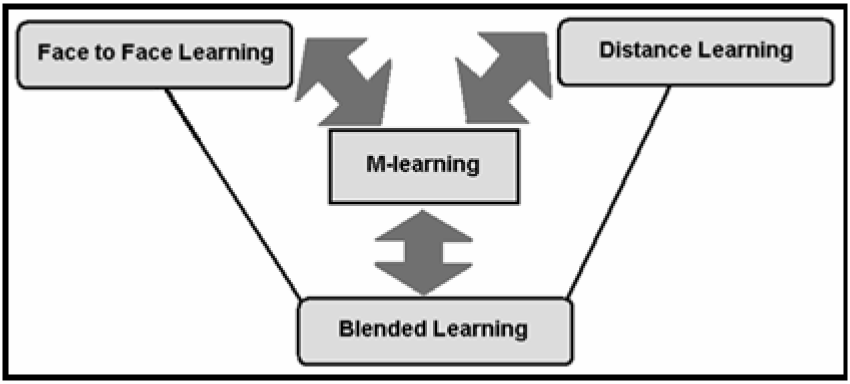

Fig. 2. M-learning: educational modalities

In particular, the teaching and learning process of Mathematics requires forms of making it more accessible to students. Mathematics taught at schools often plays an excluding role, labeling and classifying people as able or unable to participate in society's decision-making processes [21]. In this sense, taking into account the justifications for Figure 2, which point out that m-learning has a potential to contribute to learning in several educational modalities, this study proposes the mapping presented in Figure 3. It is an adaptation of that proposed in Figure 2 to the context of Mathematics.

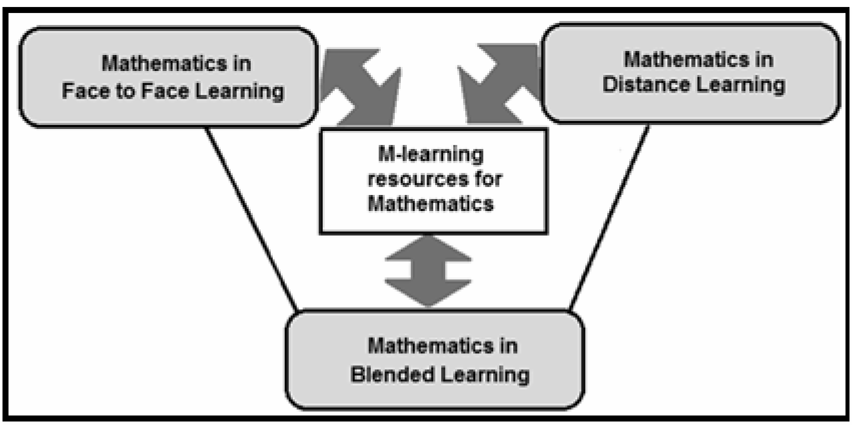

Fig. 3. M-learning in mathematical learning: educational modalities

It is important that further studies include all three modalities (Figure 3), aiming to analyze the importance of m-learning for the teaching and learning process of Mathematics. In this sense, stress should be given to the need of developing pedagogical models on which to base the knowledge building process in Mathematics through m-learning. Such models, as discussed in section 2, aim at structuring pedagogical practices, defining and outlining several aspects involved in the process.

4 Pilot Study Using Graph2Go: Building a Pedagogical Model

A pilot study using the Graph2Go[3] application was performed with the aim of developing and analyzing a pedagogical model involving use of mobile devices at a face to face experiment. This application works as a graphic calculator for a set of functions, allowing to establish connections between graphic and algebraic representation through dynamic changes.

The pilot study using Graph2Go was held in November 2009 and it lasted 4 hours. It was performed as part of a research project,[4] and the target audience was college students at Instituto Federal Fluminense Campus Campos-Centro (RJ, Brazil): eight students of Control and Industrial Automation Engineering (1st semester), and four undergraduate students in Mathematics (2nd semester).

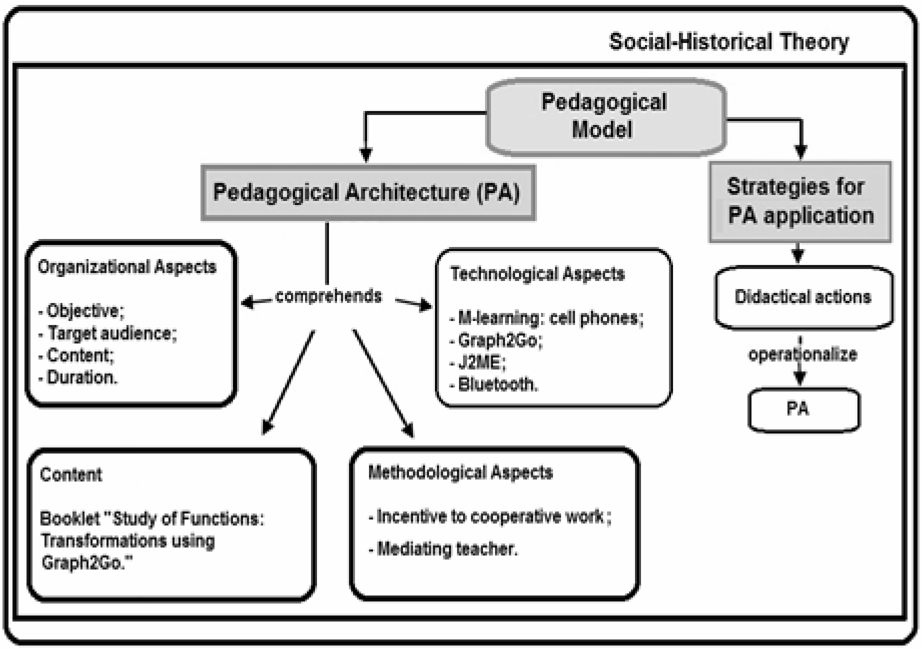

Fig. 4. Pedagogical model – pilot study using Graph2Go

The pedagogical model (Figure 4) aimed at setting the foundation for elements that would be included in the experiment, making it more structured and better defined. Answering questions in several aspects of the pedagogical model implies analyzing

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[3] Free application (for non-commercial purposes), specific for cell phones, developed by Michal Yerushalmy and Arik Weizman - project Math4Mobile (http://www.math4mobile.com/).

[4] Project "Information Technologies and Communication in the Teaching and Learning Process of Mathematics" (http://www.es.cefetcampos.br/softmat/projeto_TIC/portal.html).

and making decisions that would not often be considered in advance. Such procedures might reflect into safer actions and a lower number of unexpected situations.

As shown in Figure 4, the social-historical theory was adopted as theoretical background, providing the basis for the entire model. In this theory, mediation includes use of instruments and signs within the social context, and the combination of use for such resources allows development of superior psychological processes [22]. In addition to instruments and signs, the role of a human mediator, encouraging reflections through assistance, is also essential for student autonomy and knowledge appropriation [23].

The pilot study, defined in organizational aspects, aimed at providing the study of graphic changes of functions using Graph2Go. The target audience, as mentioned earlier, was composed by college students. The booklet[5] of activities, mentioned in the content aspect, is divided into three sections: the first has general information on Graph2Go and instructions of use; the second brings activities to study changes in graphs of quadratic functions through changes in coefficients; and the third provides a similar study to that performed with quadratic functions, but involving the sine function.

To encourage cooperative work, teacher-mediated pair activities were proposed, providing questions and reflections (methodological aspects). Interaction between individuals, according to the social-historical theory, plays an essential role in human development. A particular type of interaction stands out in this paper – mediation. Mediation takes place in the Zone of Proximal Development (ZPD - distance between real and potential development levels, determined by problem solving supervised by an adult or in collaboration with more skilled partners) and includes use of tools and signs within the social context [22]. Digital technologies are mediating tools that might contribute to creation of ZPDs, in which context Graph2Go is inserted.

With regard to technological aspects, mobile devices (cell phones) were chosen with pedagogical purposes (m-learning). Transfer of the application into the students' cell phone was performed via Bluetooth using a laptop equipped with such technology. Direct transfer of the application, from the Internet to cell phones, would be more practical, but it was avoided due to connection and download costs (the application itself is free). When the participants were selected for the study, they were told it was necessary to have cell phones with Bluetooth and J2ME platform (required by Graph2Go).

As mentioned in section 2, putting a pedagogical architecture into practice demands certain strategies. A brief description on how the proposed architecture was effectively applied is provided here. First, the application was transferred. At that time, there were a few problems: one participant who thought he had J2ME in his cell phone did not actually have it, which prevented execution of the application. Furthermore, although all cell phones had Bluetooth, some transfers were only possible through memory card. Thus, two other participants whose cell phones had the necessary requirements, but no memory card, could not have the application due to transfer problems.

After the initial stage, nine out of 12 students had the application in their cell phones. However, since the work was performed in pairs, development of activities was not impaired by this problem. The first section of the booklet, which explained Graph2Go features, was then discussed with the students. They had no difficulty

5 Available at: < http://www.es.cefetcampos.br/softmat/projeto_TIC/atividades.html>.

understanding the application resources, nor using the keys. Next, activities related to graphic changes were performed, after the importance of such theme to learn integral calculus had been highlighted. Having analyzed the graphic influence of changing coefficients in quadratic functions, students performed a similar analysis relative to the sine function. Both analyses were then commented and, based on the perception of association between them, some generalizations were discussed.

The following section brings an analysis of the experiment using data obtained from observation of the students' actions and from a questionnaire.

5 Pilot Study: Analysis of Results

In general, the students actively participated in proposed activities. Questions to the teacher – the process mediator – and exchanges with classmates showed their interest in what was being studied. There were no comments or actions that showed difficulties in using the application, and understanding of the issue was achieved.

To ensure a deeper qualitative analysis of the experiment, a seven-item questionnaire was organized, with six semi-open questions (including request of comments) and one open question. The questionnaire aimed at collecting data on the application's learning facility, advantages and disadvantages, importance for learning the theme and the role of classmate's and teacher's mediation. In general, data were collected on several aspects of the proposed pedagogical model.

None of the participants had used an application for cell phone in the study of an educational theme (not restricted to Mathematics). Even so, 75% of the participants reported being "easy" to learn the Graph2Go resources, and the remaining considered it as "very easy." Comments generally stressed the fact that the application is well organized, user-friendly, with intuitive, simple and objective resources. The percentage confirms what was mentioned about not having any evidence of difficulty by the participants when using the application.

They all considered that the booklet activities, developed with the aid of Graph2Go, collaborated to the understanding of the theme under study. The possibility of visualizing the variation of function graphic behavior by changing coefficients was the most stressed aspect by the participants. Such data reinforces the importance of using tools in the individual's development, as supported by the social-historical theory.

One of the questions was about the advantages and disadvantages of using Graph2Go. In general, advantages included visualization and movement, easy to understand and use, practicability, mobility, being free, graphs for the derivative and integral function (with possibility of changing the integration constant). Disadvantages were limitation of options of functions; impossibility to draw graphs of different functions on the same screen; language (the application is in English, with which not all students were familiar); size of graphs. It is important to analyze the potential and limitations of a didactical resource. As proposed by Cabero [24], thought should be given to adequacy of a given didactical resource to planned objectives, students' characteristics and adopted pedagogical proposal.

With regard to use of applications for cell phones for mathematical learning, 67% of the participants considered it "very important" and the remaining classified it as "important." It was stressed that, with cell phone popularization, such device is a resource that can be useful for learning. In addition, in terms of face to face learning, use of these applications would eliminate the need of going to computer laboratories. The rates are in agreement with studies on m-learning in the process of Mathematics teaching and learning [10, 11, 12].

Classmates' collaboration during activities using Graph2Go was considered as "very important" by 58% of the participants, while the others considered it as "important." In general, interaction between students was stressed as being significant to discuss proposed concepts and to better understand them. The participants' view is coherent with what is proposed by Vygotsky [22]. According to that author, shared activity is important for cognitive development, as it enables living in the external level what will be further internalized. Moysés [25] reinforces that by claiming that learning of Mathematics should always include such interpersonal action.

Teacher's role as a mediator during activities using Graph2Go was classified as "very important" by 75% of the participants; for 17%, it was "important," and for one participant (8%) it was "little important." The participants stressed that, although the application was easy to understand and use and activities were clear, the teacher's work of making students think about the concepts was essential. The justification of the student who classified it as "little important" is as follows:

> Little important because it is possible to understand the application without the teacher's help, although extremely important to help with the mathematical thought (Participant 4).

Therefore, even the participant who considered it as "little important" stressed the teacher's role as a mediator, as supported by the social-historical theory. Mediated learning goes through an active participation of a more experienced partner that selects, modifies and interprets context conditions present in the learning process of another subject that is less experienced [26].

It should be stressed that, although short, the experiment was significant. In this sense, it was possible to notice the importance of developing a pedagogical model to enable more efficient actions. The pilot study showed that: i) the difference between available devices and resources in cell phones is a setback for their use with educational purposes; ii) Internet-related costs are another factor making use of mobile devices difficult; iii) the participants' skill to deal with cell phone keys is quite favorable; iv) practicability of cell phone use (very similar to how a calculator is used, being available when needed) is a very interesting aspect in educational terms; v) it is important that pedagogical models take into account the role of teacher and classmate mediation in the learning process.

6 Final Considerations

In Mathematics, digital technologies create possibilities, allowing simulations, visualizations, experiments, hypothesis generation, among other actions. M-learning adds extra possibilities, such as practicability, mobility, reaching a higher number of people, learning in real contexts, among others. In this sense, use of mobile devices, specific applications or even general resources, such as text messages, photographs, videos, among others, can favor the process of Mathematics teaching and learning, making it more accessible and closer to the student's reality.

Studies indicate that m-learning has potentialities that might enrich the teaching and learning in several educational modalities, going beyond the initial focus on distance learning. In this sense, studies on m-learning and Mathematics should deal with distance, face to face, and blended learning. Such studies can favor not only mathematical learning, but also the very evolution of m-learning through developed resources, identification of forms of use and feedback.

Pedagogical models considering use of mobile devices in varied educational modalities can favor more structured practices of m-learning. Development of these models can allow a more consistent foundation and organization of pedagogical practices and a better use of resources, in this case, mobile devices. Analysis of the pedagogical model in the pilot study pointed to a profitable use by the students, taking into account their actions and comments and the data collected by the questionnaire. The model allowed identification of difficulties and stressed potentialities in the use of cell phones with educational purposes.

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