

Topic: Mobile learning environments and applications

M-Learning in Mathematics: mapping requirements

*Silvia Cristina F. Batista*¹, *Patricia Alejandra Behar*², *Liliana Maria Passerino*²

¹Instituto Federal Fluminense, ²Universidade Federal do Rio Grande do Sul

Keywords: *m-learning, Mathematics, Activity theory*

Abstract:

This study understands that m-learning can support e-learning actions in varied curricular areas. In this sense, this article proposes requirements for m-learning activities in Mathematics. These were organized based on studies found in the literature and conducted by the authors, as well as on concepts within Activity Theory. Thus, characteristics of such theory collaborating to its adoption in m-learning are identified. Next, general criteria for m-learning projects presented in the literature are analyzed. Finally, requirements are proposed, complementing general recommendations in the field of Mathematics.

1 Introduction

According to Wains and Mahmood [1], m-learning can enhance the potential of e-learning actions, especially relative to students' mobility and lack of Internet access infrastructure in developing countries. In this article, m-learning is thought to be a contribution to e-learning actions in several curricular areas.

Although not much frequent, studies have indicated various advantages of m-learning for Mathematics learning [2, 3, 4, 5]. The present study proposes requirements for m-learning activities in the aforementioned subject.

It is understood, however, that no matter which area is being discussed, it is crucial to have a theoretical background to guide m-learning activities, taking into account the main focus, which is learning. A literature search showed that Activity Theory (AT) has been used as theoretical background for m-learning by several researchers [6, 7, 8, 9]. According to AT, activity is the process fostering the mediation between human beings and the reality to be transformed. Such theory has also been adopted in the elaboration of proposed requirements.

In addition to a theoretical background, several general requirements are needed in m-learning. In this sense, many principles and requirements have been discussed in the literature [8, 10, 11, 12]. As mentioned earlier, this article proposes criteria for m-learning in Mathematics. Aiming at this goal, sections 2 and 3, respectively, deal with AT contributions for m-learning and present general criteria for m-learning projects, based on the literature on this subject. In section 4, requirements for Mathematics are proposed to supplement the general recommendations for m-learning. Finally, section 5 brings some considerations about the theme.

2 Activity Theory as a Theoretical Framework for M-learning

Activity Theory (AT) is based on Vygotsky's key ideas, such as mediation, internalization, development of superior mental functions, among others [13]. Thus, this theory can be thought of as a theoretical line derived from the social-historical theory [13]. In this section,

some conceptions of such theory are presented and its contributions to m-learning are analyzed.

2.1 Fundamental principles of Activity Theory

According to Leont'ev [14], what directly determines a child's psychic progress is the development of her activities, either external or internal. According to this theory, human activity fosters the mediation between human beings and the reality to be transformed. Human life, in general, can be understood as a system of activities that replace each other [15].

Activities may vary among themselves according to form, performance methods, emotional intensity, time and space requirements, among others. The main aspect distinguishing one activity from another, however, is the difference between their objects. The object of an activity is its real motive, which grants it a certain direction. Such motive can be either material or ideal, can be present in the perception, or exclusively in the imagination or in the thought [15].

In addition, two basic concepts must be distinguished: activity and action. Activities are processes psychologically characterized by what they address to as a whole. Such final goal of activity should always coincide with the motive leading the subject into action [14]. As an example, Leont'ev [14] presents the case of a student who, after learning that a given book was not required for an examination, stops reading it. Thus, the motive leading him to read the book was not the book content, but the need to be approved in the test. The book subject was not exactly what induced him to read. Therefore, reading was not actually an activity. The activity was the preparation for the examination. However, if even knowing that the book was no longer needed for the examination, the student had continued reading it or dropped it feeling sorrow, then some special need by the student had been obtained from the book content. In this case, reading of the book was an activity [14].

An action is a process whose motive does not coincide with its objective, but lies in the activity to which it is part. For an action to be performed, its objective must be understood so that it is associated with the motive of the activity to which it belongs. The objective of an action itself does not encourage a person to act. In the example given, in which the reading was interrupted, it was an action, not an activity. The motive was to pass the examination and the objective was to assimilate the book content [14].

However, an action can be transformed into activity. The activity motive can become the action objective, transforming action into activity. Transformation of motives is a consequence of the fact that the action result is more significant, under given conditions, than the motive that really induced it [14].

As far as actions are concerned, operations must be defined. These represent the mode of execution of a certain action. Actions are related to objectives, and operations refer to conditions [15]. Thus, an activity is regulated by its motivation, comprehending actions guided by different objectives. Each action, in turn, requires several operations, which are adapted to specific conditions. An activity reflects its motivation, an action reflects its goal, and an operation reflects action conditions [15].

Some studies using AT, according to Engeström's view [16], emphasized the role of mediation in the subject-object relation, but did not significantly focus on social and communicative aspects. In this sense, that author proposed an extension of the theory, trying to represent the social/collective context within an activity system, adding elements related to the community, rules, and division of labor. For a wider view, a later study is used [17], in which the author stresses the existence of three generations of AT.

The first generation is centered on Vygotsky, who introduced the concept of mediation. The basic Vygotskian triangular model presents the stimulus (S) – response (R) relation,

mediated by instruments and signs. Based on that model, Engeström [17] proposes a scheme summarizing the view of the first generation of AT (Figure 1).

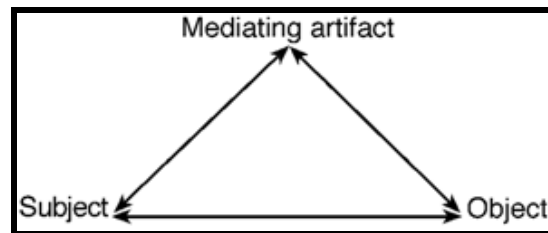


Fig. 1: First generation activity theory model. Source: Engeström [17, p.134].

The second generation has Leont'ev as its main representative [17] and Engeström himself as collaborator. Emphasizing the collective activity, Engeström [16] proposed the diagram shown in Figure 2, which represents the second generation of AT.

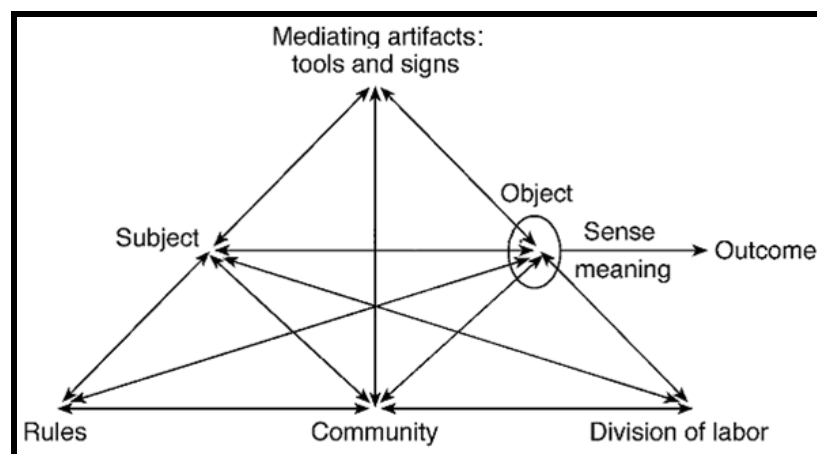


Fig. 2: The structure of a human activity system - second generation activity theory model. Source: Engeström [16, p.78; 17, p.135].

Figure 2 shows many components of the activity system and their relations of connection and interdependence. Engeström [16] added social aspects associated with activity execution to the Vygotskian model: rules, community, and division of labor. Engeström [17] explains that the elliptical figure in the diagram indicates that object-oriented actions are always, explicitly or implicitly, characterized by ambiguity, surprise, interpretation, sense making, and potential for change.

The third generation of AT, according to Engeström [17], needs to develop conceptual tools to understand dialogues, multiple perspectives, and networks of interacting activity systems. This author also proposes a model for the third generation of AT. However, it is not presented here, since the studies discussed in subsection 2.2 refer to Engeström's second generation model.

In Engeström [16, 17] the focus is on the collective activity. In those studies, there is an emphasis on the conflicting nature of social practice, which sees instability (internal tensions) and contradiction as forces of change and development.

That being so, there is an agreement with Núñez [13], who supports that AT can be an important methodological resource for the planning of pedagogical strategies. The following subsection stresses formal learning as an activity and discusses the potential of AT for m-learning.

2.2 Activity Theory and m-learning

As far as learning is concerned, AT is seen as an activity, because it aims at meeting cognitive needs [13]. In this sense, formal learning has a social, as well as an individual character, as it takes place in active interaction with other people through collaboration and communication, mediated by instruments and signs [13].

It is then understood that the very conception of learning, according to AT, includes several aspects related to m-learning: social contexts, mediation by instruments, collaboration, interaction, among others. Therefore, it is natural to have many studies pointing AT as a potential proposal to meet the characteristics of the current society and m-learning specificities [6, 7, 8, 9].

Sharples et al. [6] summarize five questions to be verified in the identification of an m-learning theory: i) is it significantly different from traditional approaches? ii) does it account for the mobility of learners? iii) does it cover both formal and informal learning? iv) does it theorize learning as a constructive and social process? v) does it analyze learning as a personal and situated activity mediated by technology?

Such questions, for the aforementioned authors, are well addressed by AT, as it considers learning as an active process of building knowledge and skills through activities within a context of a community, as previously mentioned. In addition, it not only supports the continued process of personal development, but also the fast conceptual changes of the current era [6]. Thus, the authors recommend AT to serve as basis for m-learning activities and to describe the dialectic relationship between technology and learning using a framework that is an adaptation of Engeström's diagram [16, 17].

In this framework, the authors separate two perspectives, or layers, of instrument-mediated activity: i) the technological layer, which represents the association between learning and technology, in which instruments, such as computers and cell phones, act as interactive agents in the process; ii) the semiotic layer, which describes learning as a system in which the student's actions, oriented to an object, are mediated by cultural instruments and signs [6]. According to the authors, these layers can serve as a semiotic framework to analyze learning in the era of mobility, or technological, to propose requirements of design and evaluation of mobile systems for learning. In addition, layers can be superposed to examine the dynamics and development of learning and technology conjointly [6].

Waycott et al. [7] also analyzed AT contributions to m-learning, among which the following stand out: i) possibility of analysis of how users adapt to instruments, according to their daily practice or preferences, and of how they change the object of activity; ii) reflections on contradictions [16], which contributes to the understanding of the impact of introducing a new technology in learning, both in terms of contradictions that the new tool helps to solve, such as those created by its use.

In agreement with the ideas previously described, Uden [8] supports that AT can be very useful in m-learning projects. According to the author, that theory allows analysis of the main context elements in which the activity takes place and how these can influence learning. The mentioned context includes both internal (motivations, objectives, among others) and external (artifacts, other people, environmental aspects, among others) aspects to people. There are also specific aspects related to mobile technologies (technical aspects, usability, mobility, among others). In addition, AT incorporates a strong notion of mediation (activities mediated by artifacts in internal and external levels), history (activities develop and change) and collaboration (an activity is performed by one or more individuals, aiming to obtain desired results within a community, according to a set of rules). From this perspective, Uden [8] proposes a methodology – completely based on AT – to design the learning environment and the context of m-learning use, as will be briefly explained in the next section.

Liaw et al. [9] also understand AT as a lens collaborating to the understanding of the learning process, enabling analysis of its complexity and its integration with the context. Those authors present indications of the influence of four factors (student autonomy, system functions, satisfaction with them, and system activities) in the acceptance of a management system of information for m-learning. These indicators were developed through AT-supported research, adopting the framework proposed by Sharples et al. [6].

Thus, AT, in the authors' view, has a potential to serve as background for m-learning activities, which is an area characterized by interactivity, mobility, team work, learning in real contexts, among others. In addition to defining a theory, it is important to consider that some criteria should be analyzed in m-learning, as will be discussed in the following section.

3 Survey of general requirements for m-learning

Several frameworks [8, 10, 11, 12] proposing requirements for the development of m-learning actions can be found in the literature. Such requirements do not take into account particularities of specific areas, but are essential in any m-learning activity. Considering the frameworks presented in this section, a list of general requirements is proposed at the end.

Uden [8] considers that the complexity of relations involved in m-learning can be analyzed from an AT perspective. Rooted in that theory and in related studies, Uden [8] proposes a methodology to project the learning environment and the usage context in m-learning. The proposal considers issues related to technology, social interactions, organization and development of activities, reach of forecasted goals, and analysis of contradictions, among many others. In summary, the methodology approaches four major stages, which contemplate several substages: i) organization of m-learning project; ii) analysis of learning context; iii) historical analysis of the activity, its components and actions; iv) search for internal contradictions.

Parsons et al. [10] propose a framework that can be used both as design tool for the development of m-learning activities and as an analysis tool to help understand critical success factors in finished projects. Based on the literature on the subject, these authors considered issues of design for m-learning from four perspectives that interact between themselves: i) generic mobile environment issues; ii) mobile learning context issues; iii) learning experience; iv) learning objectives.

Koole [11] proposes the FRAME model: "Framework for the Rational Analysis of Mobile Education," which describes m-learning as a process resulting from the convergence of mobile technologies, learning ability, and social interaction. FRAME can be used in the development of mobile devices and learning materials, and in the conception of teaching and learning materials for m-learning [11]. In this model, knowledge building is emphasized and Vygotskian perspectives are considered, especially relative to mediation and to the Zone of Proximal Development. Mobile devices are understood as active components, equally important for social processes and for learning. Three main aspects (device, learner, social) and intersections between them are taken into account: i) device aspect – refers to physical, technical and functional characteristics of a mobile device; ii) learner aspect – considers cognitive skills, memory, previous knowledge, emotions, and possible motivations; iii) social aspect – includes processes of social interaction and cooperation; iv) device usability intersection – intersection between device and learner aspects, contains attributes of device usability; v) social technology intersection – intersection between device and social aspects, comprehends social technologies, which describe how mobile devices enable communication and collaboration between individuals and systems; vi) interaction learning intersection – intersection between learner and social aspect, has aspects associated with the adopted learning theory in terms of social relationships; vii) mobile learning process – main intersection of the model, between device, learner and social aspects. Within such context, m-

learning can enable students to evaluate and select relevant information, redefine their objectives and reconsider their understanding of concepts in a changing reference frame, which is the information context [11].

Based on the analysis of articles included in the book “New technologies, New Pedagogies: Mobile Learning in Higher Education” [18], Herrington, J., Herrington, A. and Mantei [12] propose design principles for m-learning. These are recommendations generated from studies on Higher Education, but since they are quite general, it is possible to adapt them to other contexts.

By analyzing the requirements proposed in the studies above, taking into account AT ideas and the authors’ experience, several general requirements for m-learning were identified.

3.1 General requirements for m-learning

Next are some requirements for m-learning, regardless of curricular area:

- to verify students’ receptivity relative to the proposal of using mobile devices with educational purposes;
- to identify the mobile device to be used. Whenever possible, it is recommended to use the students’ own devices, but it is necessary to:
 - analyze their physical, technical and functional characteristics. This includes evaluating, for example, limiting factors of use and their implications on the development of activities. For example: screen size, connection and download costs, practicality of use, storage capability, among others;
 - be alert to problems resulting from the variety of resources of each device model;
 - allow previous recognition of resources, because even if the device belongs to the student, it does not mean that he/she is familiar with all available resources. In this sense, a probing questionnaire is recommended to better understand the relationship between the user and the device.
- to identify which parts of the activity must be supported by mobile technologies and which parts are better supported by other technologies (or even none);
- to identify the means by which the communication between involved people is given;
- to encourage interaction between people using mobile devices;
- to foster integration of mobile and non-mobile technologies;
- to encourage conscious and critical use of digital resources, as well as analysis of the information obtained through them;
- to analyze the learning context, both in terms of internal (motivations, objectives, among others) and external (instruments, involved actors, environmental aspects, among others) aspects to people;
- to identify the motives of each proposed activity;
- to identify actions to be executed and objectives to be achieved through them, as well as operations to be performed;
- to reflect on the role of technological devices, such as mediating artifacts, knowing that material instruments represent methods and operations, not objectives;
- to understand the teacher’s role as a human mediator. The teacher’s actions should lead students to feel the need of concepts to be addressed, so that the activity motive coincides with the study object;
- to understand the student’s role in the learning process, his/her motivations, interests, study skills, among others. In addition, to understand the role of classmates, who also act as human mediators;

- to analyze changes in the teacher-student relationship associated with use of mobile devices;
- to consider studied concepts as means of performing complex actions, which should be built by students in a conscious manner;
- to analyze the development of activities, trying to understand the nature of changes occurring in different stages;
- to identify internal contradictions: primary, secondary, tertiary, quaternary [16].

4 Requirements for m-learning activities in Mathematics

In this section, requirements were organized into two groups: i) requirements based on Davydov's ideas [19], which are valid for any mathematical activity, including m-learning; ii) specific requirements for m-learning activities in Mathematics. Such requirements were classified according to research studies found in the literature and conducted by the authors.

4.1 Requirements based on Davydov

Rooted in Vygotskian principles and in AT conceptions, Davydov [19] claims that the teaching essentially based on empirical thought does not foster the student's mental development. In this sense, for that author, school must provide content adequacy so as to enable development of theoretical thought [13].

Davydov [19] distinguishes between two types of thought: empirical and theoretical. Empirical thought has an external, immediate character associated with practice. On the other hand, theoretical thought is focused on internal relations between objects and phenomena. It is a mediated, reflected thought that operates through scientific concepts and has essence as its substance. Theoretical thought has its own specific content, comprised of objectively interconnected phenomena in an integral system. This thought should gather objects that are different and indicate their part in the overall system [19].

As far as Mathematics is concerned, Davydov [19] presents several guidelines to form a mathematical theoretical thought, understood here as important for m-learning activities:

- to consider that the logic of theoretical thought formation goes from general to its particular manifestations. The process of general knowledge must prevail over the process of particular and concrete knowledge – the latter should derive from the former;
- for each topic addressed, present situations that gave origin to it. Concepts should not be presented as ready knowledge. Understanding a concept as human production is the foundation for organizing the theoretical thought;
- to guide students in a problem situation, whose solution requires the new concept;
- to consider that the main thing is not correctly solving the problem itself, but the thought involved in the resolution, which must provide generalizations;
- to identify the general relation serving as basis for problem solving. The general relation is that lying on the foundation of several phenomena, whose understanding contributes to understanding the association between them;
- to establish a graphic or symbolic model enabling study of the basic principles of the general relation;
- to develop specific activities to allow studying such basic principles. These activities should later pass through a mental plan (internalization).

4.2 Specific requirements for m-learning activities in Mathematics

- to organize strategies enabling to explore resources of the device itself to study mathematical themes: videos, photos, songs, among others;
- to develop pedagogical materials that can be studied/answered through the adopted mobile device. In this sense, it is important to consider that typing mathematical formulas and symbols can be problematic in mobile devices;
- to understand that use of mobile technology should collaborate to individual reflections and to collective analyses of mathematical concepts;
- to use mobile devices to contribute to the development of autonomy in the exploration of mathematical themes, as well as to learning in real contexts;
- to organize the activity structure according to Engeström's diagram:

Figure 3 shows an adaptation of Engeström's diagram [16, 17] to the context of m-learning in Mathematics:

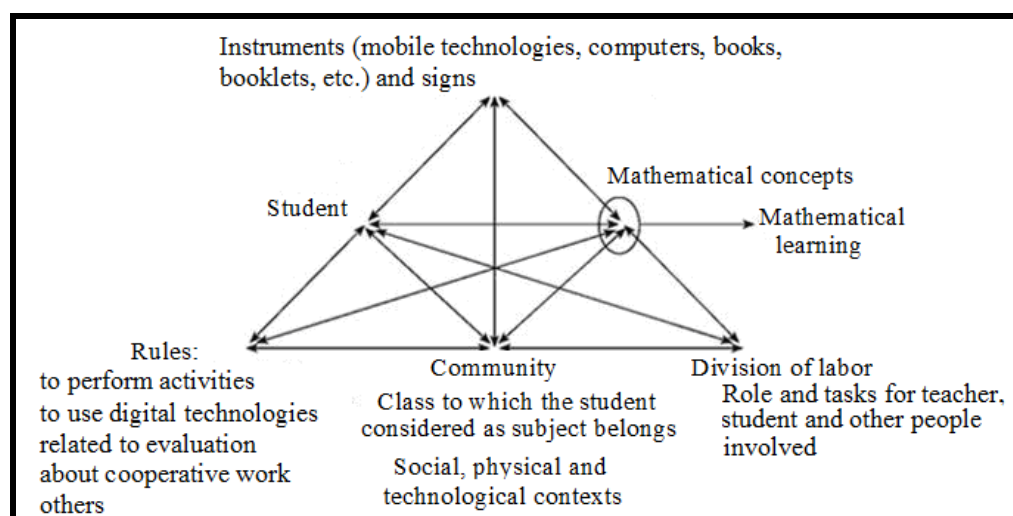


Fig. 3: Activity structure within the context of m-learning in Mathematics

Figure 3 considers the following: i) subject – student enrolled in a Mathematics class; ii) object – mathematical concepts; iii) result – mathematical learning; iv) instruments – mobile technologies, computers, connection networks, books, booklets, among others; v) rules – relative to activity execution, use of digital technologies, type of evaluation, collaborative work, among others; vi) community – class to which the student considered as subject belongs, in addition to social, physical and technological contexts involved; vii) division of labor – role and tasks of teachers, students and other people involved in the activity.

- to select applications that can subsidize study of the theme according to the adopted device. In this sense, it is important to consider that the application should:
 - present an adequate interface to the target audience;
 - have user-friendly interface features (icons, menus, etc.);
 - present conventions and definitions relative to Mathematics in a correct manner;
 - enable development of thinking abilities and problem resolution;
 - enable dynamic visualization and investigation of mathematical facts;
 - contribute to the construction of mathematical abstractions, avoiding mere memorization of algorithms;
 - allow content exploration consistently;
 - enable development of the ability to critically evaluate information;

- facilitate understanding of Mathematics as a communication language through which it is possible to model and interpret reality.

The requirements presented in this and the previous section comprise a model for m-learning activities in Mathematics, which is being developed.

5 Final Considerations

Popularization of mobile devices is a favorable aspect to these technologies in educational terms, due to the possibility of reaching a large number of people with no need of physical displacement. However, in addition to this aspect, there are several others, such as interactivity, mobility, practice of team work, and learning in real contexts, which have motivated studies associating mobile technologies and education. Within this context, e-learning may benefit from such m-learning potentialities.

In this study, m-learning can collaborate to Mathematics learning and, in this sense, it is crucial to meet some requirements. Mobile devices have their own potentialities and limitations, which evidences the need of considering certain m-learning criteria for any curricular area.

Sets of requirements sometimes are already associated with or take into account a basis theory, which shows advances in m-learning in terms of approximating it to the pedagogical area. AT is thought of as a proper theoretical background for m-learning. This view, however, does not exclude the possibility of considering other theories for this purpose.

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Author(s):

Silvia Cristina, Batista, M.Sc., Ph.D. student of Information Technology in Education
Instituto Federal Fluminense, Department of Mathematics
Rua Dr. Siqueira, 273 - Campos dos Goytacazes, RJ - Brazil - CEP 28030-130
Email: silviac@iff.edu.br

Patricia Alejandra, Behar, Ph.D. and Liliana Maria, Passerino, Ph.D.
Universidade Federal do Rio Grande do Sul, Graduate Program in Information Technology in Education
Av. Paulo Gama, 110 - prédio 12105 - sala 332 - Porto Alegre, RS - Brazil - CEP 90040-060
Email: patricia.behar@ufrgs.br; liliana@cinted.ufrgs.br