ACTIVITY THEORY AND M-LEARNING IN THE TEACHING OF CALCULUS

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ABSTRACT

Due to its educational purposes, mobile learning (m-learning) is a field of study that comprises several aspects, besides technological ones. Therefore, it requires theoretical support to guide actions in the process. This article aims at presenting a pedagogical experiment based on Activity Theory, with use of cell phones in Calculus I classes, and some conclusions derived from it. The paper begins by presenting the main concepts of Activity Theory, and a brief account of how it has been used in m-learning studies. This is followed by an overview of the subject Calculus I, and methodology used in its teaching. The article closes with considerations on the experiment in view of the theoretical framework, with special attention to the possibility to observe the potential of Activity Theory to support m-learning activities.

KEYWORDS

Activity Theory, M-learning, Cell phones, Calculus.

1. INTRODUCTION

As access to information increases regardless of time and distance, the role of education, especially that of formal education, has been questioned and challenged. Relations among education, society and technology are progressively more dynamic – a context in which Mobile Learning (m-learning) may contribute as research advances in the area (Traxler 2009).

M-learning is a research field which aims at analyzing how devices can contribute to learning, and presents features such as interactivity, mobility, group work, learning in authentic situations, among others. It is, therefore, an area that demands further studying, both in its technological and pedagogical aspects (Traxler 2009). Considering the special features of m-learning, it is important to analyze theories that can support it. Thus, this paper discusses Activity Theory (AT) as a theoretical framework for m-learning.

According to AT, which was developed primarily by Russian psychologist Alexei N. Leont'ev, activity is the process that promotes mediation between the human being and the reality to be changed. This is a dialectic relation, as not only the object is changed, but the individual is also psychologically modified (Núñez 2009). Studies in the literature have indicated factors that justify adoption of AT as a theoretical framework in m-learning projects (Sharples et al. 2005; Waycott et al. 2005; Uden 2007).

This study describes, and presents considerations about a pedagogical experience involving cell phones in Calculus I classes. The methodology was based on AT, and took into consideration technological resources in addition to mobile phones. The experiment took place in the first semester of 2011, with two college level groups of students at a federal institution (traditional classroom). Section 2 presents the basic concepts of AT, and discusses how it has been adopted, in the literature, as a framework for m-learning projects. An overview of Calculus I, and the methodology used in its teaching are presented in Section 3. In Section 4, results of the experiment are considered from an activity theory perspective. Section 5 closes by presenting final remarks about this study.

2. ACTIVITY THEORY

Vygotskian ideas make up the foundation of Activity Theory (AT). It focuses on activities developed by individuals, and on the diverse relations resulting from them. Activity is considered responsible for the mediation between humans and the reality to be transformed.

AT is based on Vygotsky's key concepts, among others: mediation, internalization, development of higher mental functions (Núñez 2009). However, as explained by Kozulin (2003), for Vygotsky, consciousness is mediated by signs, while for Leont'ev, mind and consciousness are mediated by tools and objects.

Activities may vary according to form, method, emotional intensity, time and space requirements. The main distinguishing feature of activities is the difference among their objects. The object in an activity is its true motive, which gives it a determined direction (Leont'ev 1978). The reason for this may be material or mental, it may be present in perception or, exclusively, in the imagination or thought (Leont'ev 1978). However, it is important to consider that certain activities are more relevant for the subsequent development of the individual than others and, therefore, are considered as the principal ones (Leont'ev 2001).

It is also essential to show the difference between two concepts: activity and action. Activities are processes psychologically characterized by their purpose, as a whole. This final objective of the activity must always coincide with the reason that triggered the individual to act (Leont'ev 2001). An action is a process that aims at collaborating for reaching the motive of the activity. Thus, for an action to be executed, its objective must be understood in association with the motive of the activity it belongs to (Leont'ev 2001).

However, an action can be transformed into an activity. The motive can become the object of an action and, thus, the action becomes an activity. The transformation of motives comes from the fact that results of an action are more meaningful, in certain situations, that the motive that actually elicited it (Leont'ev 2001).

Furthermore, operations must be defined. These represent how actions are performed. Actions are related to objectives, and operations are associated to conditions (Leont'ev 1978). In short, an activity is regulated by motivation, and comprises actions guided by distinct objectives. Each action, in turn, requires several operations which adapt to specific conditions. An activity reveals its motivation, an action reveals its goal, and an operation reveals the conditions of the actions (Leont'ev 1978).

Nevertheless, Engeström (1987) says that some studies based on AT emphasized the role of mediation in the subject-object relation, but did not focus, in a meaningful way, the social and communicative factors. The author proposed, then, an expansion of the theory, aiming at representing the social-collective context within an activity system, by adding elements related to the community, rules and division of labor. However, for a more comprehensive view, one should look up a prior study (Engeström 2001), in which the author emphasizes the existence of three generations of AT.

The first generation is centered on Vygotsky, who introduced the concept of mediation. The basic vygotskyan triangular model presents the connection Stimulus – Response, mediated by tools and signs. The second generation has Leont'ev as main representative (Engeström 2001), and Engeström himself as a collaborator. Emphasizing collective activity, Engeström (1987) proposed the diagram representing the second generation of AT (Figure 1), which shows the various elements of the activity system, and its interrelations. Engeström (1987) added social aspects related to activity to the original vygotskian model: rules, community, and division of labor.

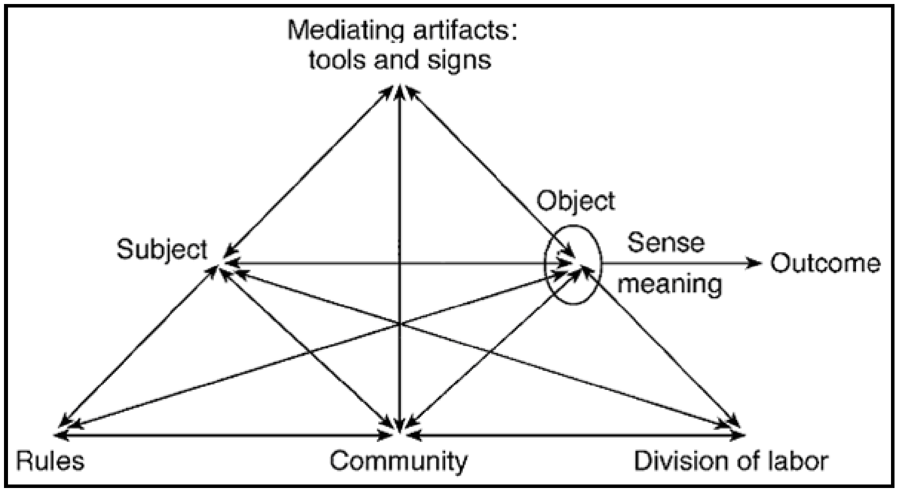

Figure 1. The structure of a human activity system - second generation activity theory model
Source: Engeström (1987, p.78; 2001, p.135).

In the diagram, the oval figure indicates that object-oriented actions are always, implicitly or explicitly, characterized by ambiguity, surprise, interpretation, sense making, and potential for change (Engeström 2001).

According to Engeström (2001), AT's third generation must develop conceptual tools in order to understand dialogue, multiple perspectives, and networks of interactive activities. The author also proposed a model for the third generation of AT. Nevertheless, this model is not presented here as both the studies discussed in Section 4, and the experiment described in Section 5 follow Engeström's model for AT's second generation (Figure 1).

In Engeström (1987; 2001), the focus is always on the collective activity. In his works, he emphasizes the conflicting nature of social practices, which regards instability (internal tensions) and contradiction as forces of change and development.

As to learning, AT considers it as an activity since it aims at satisfying cognitive needs (Nuñez 2009). In this approach, formal learning has a social character which goes beyond the individual, as it takes place in active interaction with other people, through collaboration and communication, and mediated by tools and signs (Núñez 2009). Davýdov (1930-1988), based on contributions by Vygotsky, Leont'ev e Elkonin, expanded the characterization and understanding of the learning activity. The objective of the learning activity, in Davýdov's view (1982), is the domain of the theoretical knowledge, that is, the domain of cultural symbols and instruments available in society, and obtained by learning in the various fields. Davýdov (1982) distinguishes two types of thought: empirical and theoretical. Empirical thought has an external and immediate nature; it is related to practice. Theoretical thought, on the other hand, is related to the essence, to internal relations among objects and phenomena. For Davýdov, teaching strictly based on empirical thought does not result in the mental development of the learner.

Regarding development of the theoretical mathematical thought, Davýdov (1982) says that each topic in the curriculum should start by a detailed introduction, presenting situations which originated the need of the respective theoretical concepts. Following, concepts should be built from these steps: i) student guiding in a problem situation, in which the solution requires a new concept; ii) identification of the relation that grounds problem solving; iii) establishment of a symbolic model that allows for the study of properties in "pure form"; iv) identification of the properties of the observed relation, through which it is possible to infer the conditions and resolutions methods of the original problem (Davýdov 1982).

In this study, AT is used according to the principles proposed by Leont'ev, and contributions by Engeström, particularly those regarding collective activities. Furthermore, Davýdov's contributions are used due to their relation to the teaching of Mathematics.

2.1 Activity Theory as Theoretical Framework for M-learning

This subsection presents an analysis of studies that show the potential of AT to serve the specific features of m-learning. This does not mean that other theories cannot be used. Patten et al. (2006), for example, think that constructive/constructionist, contextual and collaborative principles are, in general, adequate to m-learning. Therefore, this section focuses on AT, but keeping in mind that other frameworks could also be used.

Sharples et al. (2005) propose five questions to be tested in the identification of a theory for m-learning: i) is the theory significantly different from traditional approaches? ii) does it allow checking mobility of learners? iii) can it be used both in formal and informal learning? iv) does it theorize learning as a social and constructive process? v) does it allow understanding learning as a personal and situated activity mediated by technologies?

According to the authors, AT provides adequate answers to those questions because it considers learning as an active process in building knowledge and skills by means of activities within the context of a community. In addition, it supports not only the continuous process of personal development, but also the fast conceptual changes of contemporary society. Thus, Sharples et al. (2005) endorse AT to support m-learning activities.

Waycott et al. (2005) also analyze AT contributions to m-learning, among which: i) possibility of analyzing how the user adapts to the tools, according to his/her practice and preferences, and how they transform the activity object; ii) considerations on contradictions (Engeström 1987), which contributes to the understanding of the impact of new technologies in learning – contradictions the new tools help to solve as well as those created by their use.

Confirming these ideas, Uden (2007) thinks AT can support m-learning projects. According to the author, AT allows for the analysis of the main elements of the context in which the activity takes place, and how they may influence learning. The context comprises internal aspects (motivations, objectives, among others), and external ones (artifacts, other people, environmental aspects, etc.). There are also specific aspects related to mobile technologies (including: technical features, usability, and mobility). Furthermore, AT incorporates a strong notion of mediation (activities are mediated by artifacts, both internally and externally), of history (activities develop and change), and collaboration (an activity is carried by one or more individuals, aiming at obtaining desired results, within a community, and according to a set of rules).

Therefore, AT as seen by the aforementioned authors, has the potential to support m-learning – an area characterized by interactivity, mobility, group work, and real-life learning environments.

3. TEACHING CALCULUS I: A PROPOSAL SUPPORTED BY ACTIVITY THEORY

In teaching Calculus I (1st semester of 2011) to two college-level classes at a federal institution, we made an experiment of a methodological proposal using cell phones. These classes were: 1st period of Information Systems, Bachelor's Degree (daytime classes), and 1st period of Systems Analysis and Development, Technologists (evening classes). Both are conventional classroom courses with the same number of hours (80 h) and content (Limits and Continuity, Derivatives, Integrals).

The qualitative experiment was a case study. For data collection, the following techniques were used: observation, registers in the virtual learning environment, and questionnaires. The methodological proposal was based on AT, and the adopted mobile device was the student's own cell phone. The course management system used was Moodle, with MLE-Moodle (a plugin that enables extending Moodle functions to cell phones – available at http://mle.sourceforge.net/mlemoodle/index.php?lang=en).

In addition to these, several other aspects were common to both classes (content, materials, group activities, integration of different technological resources, among others). Therefore, it was possible to organize a series of common strategies for both courses, such as: i) use of technological resources, especially mobiles, as mediating artifacts – collaborating means to reach the main motive of the discipline; ii) group activities based in problem solving; iii) discussion of the historical origin of each topic (Limits, Derivatives and Integrals); iv) incentive to generalizations, thus contributing to the development of mathematical thinking (the objective is not the solution of specific questions, but the acquisition of tools to solving various questions); v) an understanding that the student is the agent of his learning process, that the teacher acts as mediator, and that the exchange of knowledge among peers is an essential factor.

According to AT, activities are a collective system with tools, rules, and division of labor. People interact to transform the object according to a common motive. The subject Calculus I, in each of the observed classes, was considered as activity system. In such systems, several actions were carried out, aiming at a greater motive – acquisition of knowledge related to the program content. As explained by Sforni (2004), in formal education, learning, as activity, aims at knowledge acquisition. Thus, considering the activity structure proposed by Engeström (1987), Figure 1, the following elements of the activity system were identified:

- Subject: each student of Calculus I in two courses – Information Systems (Bachelors) and Systems Analysis and Development (Technologists);
- Learning object: topics in Calculus I (Limits and Continuity; Derivatives and Integrals);
- Result: the activities aimed at developing: i) theoretical and mathematical thinking (Davýdov 1982); ii) mathematical foundations related to Calculus I contents; iii) ability to apply Calculus I knowledge and methods in problem-solving by stimulating hypothesis formulation, and selection of strategies of action; iv) interpretation and critical analysis of the results; v) ability to use, in a conscious way, resources found in calculators, computers and mobile phones in solving Math problems;
- Instruments: cell phones, teacher's notebook, LCD 42" TV sets available in the classrooms, wireless Internet connection available in the institution (including access for students' mobile devices), applications and quizzes for mobile phones, computer software, calculators, Moodle learning platform (with MLE plugin), books, xeroxed materials, exercise sheets;
- Rules: main guiding rules in the first semester of 2011 were: i) two grades accounting for student participation in the activities (10%), extra class work (20%), and individual tests (70%); ii) group activities based on problem solving, and supported by learning resources for cell phones; iii) participation in discussion forums available in the virtual environment;
- Community: made up of students, the teacher, the course coordinators, and department directors of the aforementioned institution. It is important to emphasize that the school offers computer labs for academic activities.
- Division of labor: several activities were done in groups. These were organized by the students themselves, and the actions for solving the activities were also negotiated among them. The teacher was responsible for organizing activities intentionally meant for the development of mathematical thinking, always taking into consideration that they should have clear objectives (the student should be fully aware of what he was searching for).

The various mediating relations which take place among these elements, indicated in Figure 1, are an evidence that learning results from a collective activity, in which each component influences the whole. Thus, these elements and the relationship among them were always taken into consideration throughout the experiment.

In the beginning of the school semester, 27 bachelor students and 41 technologists answer the questionnaire. This had questions related to cell phones, to the use of resources, to their ability of using the keyboard, and to the use of mobile devices in education, among other topics. Data was analyzed and guided several actions in the program. It was possible to observe that: i) the mean age in the two groups was, respectively, 20 and 23 years of age; ii) all students had cell phones, regular or smartphones, but with high predominance of regular devices (nearly 26% of the bachelor students had smartphones, and approximately 17% of the technologists); iii) all students were in favor of using mobile devices in education; iv) as to the ability of using the phone keys, no student rated it as "very bad", and only one rated it as "bad".

Due to the fact that not all students could use the Internet on their phones, a strategy was devised in which quizzes on the subject were presented in two different ways: via MLE-Moodle (for those with Internet connection), and via MyMLE, an open source computer program that allows the creation of quizzes for mobile phones on Java ME platform, with no need Internet connection. (http://mle.sourceforge.net/mymle/index.php?lang=en&page=download.php).

Besides MLE-Moodle and MyMLE, two applications for cell phones were used: Graphing Calculator (http://www.getjar.com/mobile/36442/graphing-Calculator/), and Graph2Go (http://www.math4mobile.com/download). Both apps are free, and require Java ME platform. They enable graphic analysis of functions, and were used to support problem-solving activities.

Guidelines to using the apps were available in the Moodle environment, as well as mobile tags (2D codes, similar to bar codes, but with two dimensions) referring to the URLs, in order to facilitate access for those with Internet connection. Students without such connection transferred the applications to the computer and, then, sent them to their phones, via Bluetooth or USB cable, for instance.

Therefore, mobility, in the discipline described here, was considered in the use of: i) MLE-Moodle resources, which allow access to the course at any time and location; ii) applications for cell phones, which took place in the classroom or not; iii) quizzes which, like the applications, could be accessed from anywhere, and with no need of an Internet connection.

4. CONSIDERATIONS IN VIEW OF ACTIVITY THEORY

The analysis of an activity, understood as a collective system, requires the understanding of the individual, the different elements, and the interaction among them. As such, there are several multiple factors acting in a collective construction. As mentioned in Section 3, Calculus I, in each of the observed classes, was considered an activity system.

In the beginning of the semester, most students were entering their college program. Contents in Calculus were quite different for them, as they demand a number of pre-requirements and abstractions. Therefore, students had to become familiar with the pedagogical proposal for the subject Calculus, as well as the methodology, strongly supported on technological resources. It must be emphasized that 54 of the 68 students who answered the initial questionnaires (around 79%), said they had never used any software for studying Math. Most of the 14 students who had used software for learning Math were repeating the academic semester, with some experience in using computer programs from the previous year. Therefore, even typing functions in the Graphing Calculator was a novelty for most learners (even though this kind of typing is similar to most Math computer programs).

It is important to take into account that knowledge, according to AT, is internalized in a particular way, being processed and transformed according to the individual's reality, and to his historical experience. Thus, students' initial difficulties can be associated to their entering a college program, to their prior educational experience (which, in general, does not make use of digital technologies as pedagogical resources), and, also, to the specific characteristics of Calculus. At the start of the school semester, students did not feel they were members of a group, as they were still getting to know one another, so that the notion of collectiveness was still being built. In other words, understanding initial difficulties demands understanding, even if somewhat superficially, the particular context of those students in their process of joining the institution.

After this month long stage of adaptation, it was possible to observe that the adopted strategies were being developed in a more natural way. Students became more familiar with the various technologies. According to Wells (1998), when the individual uses instruments to reach the objective of an action, this can be understood as an operation, the means through which the action is performed. However, when students are still learning how to use the instruments, the use itself is still an action, since it is a conscious process. Thus, one can say that learners, at the beginning of the semester, dealt with technologies in the level of actions. As such actions reached a certain degree of maturity, and started to be performed without demanding so much attention, technology use became an operation.

Problem-situations were also gradually understood more easily. Their purpose was to change concepts into cognitive needs, and lead the student to act consciously in search of solutions. It is not enough to know de definition of a concept; this must be used to solve different practical and theoretical situations (Núñez 2009). Developing problems proposed in the program was a group activity, by promoting interaction among participants, and collective search for solutions. Applications for cell phones were instruments that functioned as mediator between students and the object of knowledge. It must be stressed that of all cell phone resources, applications drew the most attention of students due to their convenience. Most learners used them with ease, at the level of operations.

It is also worthy mentioning that not all students had mobile phones with Java ME, a necessity for the pedagogical resources. Among the bachelors, around 70% of those who answered the initial questionnaire had it in their phones. Among the technologists, this percentage was around 61%. Those who had no Java ME in their phones worked in groups with others who did, so that they too could participate in discussions about the applications. As for the quizzes, it was possible to answer them in the Moodle environment. This alternative was open to all learners, but those who could do them via mobile phone were stimulated to do so and, thus, optimize their timing.

Nevertheless, solving quizzes on cell phones, considered as important by students, was not a practical process for those who had no easy access to the Internet. They had to transfer and install each series of the quiz in the device. So, in general, students transferred only part of the series. We can view this situation as a secondary contradiction (Engeström 1987). This type of contradiction occurs among the elements of the system, in this case, among the quizzes (instruments) and some students (subjects). The quizzes for those students were relevant, but not practical. Such contradictions are seen as forces of change and development; they are starting points to new solutions. For those who had connection to the Internet via cell phones, the process was more simple as they could use the MLE-Moodle.

The analysis of the evolution of the activities in both groups show good acceptance of the proposal for using technological resources in the educational context. In general, students had a responsible and cooperative attitude, making use of resources as mediating instruments in learning. Those who concluded the school semester (13 bachelors and 26 technologists) answered the final questionnaire, providing support to this analysis. Regarding the statement "The use of various technological resources to support the discipline has contributed to your learning process", approximately 38% of the bachelor students *totally agreed,* and 54% *agreed.* Among the technologists, around 77% *totally agreed,* and 19% *agreed.* Greater acceptance by technologists (evening class) can be explained by the fact that they have less time to study, and the technological support played an important role in their learning.

When asked "The proposed use of cell phones was, in general, important for the program", about 31% of the bachelor students *totally agreed*, and 31% *agreed*. Among the technologists, approximately 35% of the students *totally agreed*, and 31 *agreed*. As mentioned above, not all students had phones with Java ME, which may have contributed to the fact that the proposal, though considered as relevant by the majority, did not reach a percentage above 70%.

5. CONCLUSION

In Calculus I, the use of cell phones was a strategy to expand the possibilities of accessing course materials, as well as to provide a more convenient technological support that would aid in analysis and discussions. The use of such devices, however, was a strategy associated to several others, making up a methodology fully grounded on AT. Even though the experiment was positive, we think the popularization of smartphones will make the pedagogical use of mobile devices a more convenient practice. Devices too many technological limitations constrain, and make their use not quite viable.

As to AT/m-learning, the theory provides an adequate theoretical framework for actions in the area. According to AT, learning has a social character, going beyond the individual, as it takes place in the active interaction with others, and mediated by instruments and signs. Students are active agents of their learning process. So, the concept of learning, according to AT, embraces several aspects applicable to m-learning: social contexts, mediation with instruments, collaborations, interactions, etc.

In the experiment, this notion proved to be entirely coherent, as AT contributed to: i) the organization of activities, allowing the understanding that several aspects should be taken into consideration since the system of activity has many dynamic and interdependent elements; ii) the development of actions, providing guidance, and keeping the specific mediating role of technological instruments, as well as the roles of students, teacher, and peers in the learning process; iii) the analysis of the activity, contributing to the understanding of the nature of change that took place in the different stages, and the internal contradictions that always come up in a system of activity. We should emphasize, however, that the option for AT does not reduce the relevance of analyzing and considering other theories to guide m-learning activities.

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