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Planning lessons: A socio-historical-cultural approach in physics teaching

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Abstract
This paper investigates physics teacher class planning and its consequences during implementation in class mainly focusing the contradictions emerged among teacher's and students' expectations of the class. This situation is analysed from a socio-cultural-historical point of view mainly supported by Activity Theory. We highlight the components of the activity and the context in which they are reorganized exploring the complexity of the dialogical classroom situation. Through the use of video recordings of an experimental task we showed students measuring and isolating relevant variables to characterize a simple pendulum. We point out important aspects of the different moments of a teacher's planning, organization and the importance of dialogic interaction in the classroom to overcome lack of communication.
Keywords: *Activity theory, context, planning, dialogical interaction.*

Introduction

Among others attributes, planning courses, didactic materials development and time management are skills that are mainly expected from teachers. To plan, implement, and evaluate a physics course, even though they are expected skills, its implementation in the classroom implementation is not quite so simple. During classes a lot of tensions appear between the previous meticulous planning of activities and the need for flexibility when meeting students' local demands. However, when implementing innovations the indispensable ability to plan should be rethinking to deal with the uncertainties raised during the activity. In this paper we review the concept of planning under a socio-historical-cultural perspective. Based on socio-historic-cultural theories we discuss a wider research programme where we look for elements so as to rethink the teaching-learning process, including other indispensable educational phenomena such as dialogue; teacher and students' interaction; concepts formation and teacher's coordination of actions during classroom sessions. We deal with those aspects specifically within science education, but at the same time we are aware that this kind of research is trying to find ways to model the complex social dynamics of classrooms in general.

Classroom dynamics is an issue that have been a concern for many educational researchers. Generally, the influence of the subject content on the teacher's planning

(Yinger, 1980, McCutcheon, 1980; Symington, 1980, 1982; Symington & Hayes, 1989, Cleary et al., 1994) or how pedagogical content knowledge affects teachers previous planning (Sanders, 1992) are central issues. Ingber (2009 p.32) in a meta-analysis of research, synthesizes research emphasis, pointing out that "understanding the relationship between teacher knowledge and their practices, like planning, is important for policy if the rationale for changing policy is to improve student learning".

"Planning" common sense is associated with the capacity of an individual to plan. However, when inserted into a specific educational context, "planning" is an ongoing process of decision making to choose future actions. In this sense, planning becomes an essential human activity, i.e., to think before to act, to organize their actions and to adjust resources, purposes and values (Padilha, 2005). "Planning" often is used as something static that must be accomplishing without modifications. From this perspective, "planning" a class ends when the teacher begins the lesson. Therefore it is impossible to thinking about any student's influence in the teacher's planning.
Tavares et al. (2009) observed teachers' performance in a hospital class, highlighting the problems to plan classes in an unpredictable school environment. Consequently planning ceases to be an obvious and a mechanic task based on pre-planned action inserted into a teaching activity. Although online planning is evident in the context of the hospital class, it is also present in regular schools, showing the contradictions between the planning and its execution. The change of a context to another imposes on the teacher the need to reorganize his/her teaching activity (online planning).

The nucleus of this paper consists of putting forward another perspective to understand the "planning" and the teachers' in-action decisions within the classroom to overcome the contradictions among the teacher's planning script and its execution at classroom with the students. Our main argument here is to point out the crucial need of dialogic interaction to deal with the uncertainty of planning execution pointing out how teacher-students communication lacunas are produced from the Activity Theory perspective.

In this view, we intent to characterize and understand the teacher's online planning at a regular high school class. We present a case study conducted at a private Brazilian high school to deal with issues associated with the development of class planning, structuring and organizational processing.

Framework

We use Activity Theory for analyzing teachers' class planning at regular schools from a socio-cultural-historical approach. This theoretical scope allows us to understand the school activity as a complex system of activities.

Activity Theory has its historical roots on classical German Philosophy, Marxism and the Vygotsky, Leontiev and Luria arm of cultural-historical psychology (Engeström, 1999). Considering the theory scope it is possible to say that it have two main principles: i) it is based on mediated action, a Marxist heritage in which man acts in the world and interacts with others, necessarily mediated by cultural tools; and ii) there is a tight connection between development of the activity and development of the human psyche. This relation creates a gateway to understand the psyche through understanding the activity to which man belongs. So the complexity of the activity is reflected in the complexity of the psyche (Mattos et al., 2008). In this work we are based predominantly on Leontiev's branch of Activity Theory (Leontiev, 1978). Leontiev (1978) advanced on Activity Theory, severalising various elements that compose it. Human activity is seen as heterogeneous and poly-phased. Every activity has a motive that drives it. Considering the activity of studying physics, we are able to point to a lot of different motives to do it, some extrinsic to the activity such as to get good grades or please the parents, and some intrinsic to the activity as to understand the world, to solve practical and mathematical problems or to get professional formation etc. The activity is also composed of actions with their specific goals. For instance, to study physics, we may have to borrow books from the library and read them, select and solve exercises, undertake experiments, etc. Every action has its own goal that considered alone does not allow understanding of the general school activity, but this action, coordinated with several others, composes the activity. However, each action is composed of several operations each with its specific material conditions for undertaking this operation. The action of borrowing a book from the library requires the coordination of several operations, such as using a membership card, going to the library, finding the book required, etc. These operations are subordinate to the material conditions, in the sense that they depend on the availability of the book, opening hours of the library, etc. This quotidian example helps us to understand the organization of the activity at different hierarchical levels (i.e the activity, action and operation levels) and their feedback interactions. This complex structure emerges from the coordination of these levels within the activity (Mattos et al., 2008; Tavares et al., 2009). Besides some criticism (Davidov, 1999) Activity Theory can be seen as a powerful tool to describe and analyse "classroom phenomena", in particular physics teacher's class planning which begins before class, but concludes only when the lesson has finished. To understand the structure of an activity it is necessary to recognize the role of actions and operations, which only acquire sense if thought of inside the context of the activity. Context as a dynamic variable changes and besides reorganizing an activity, it also redefine the meaning of the actions and of the operations composing the activity, changing also the dynamic relation among them. Therefore, the activity dynamics changes within context dynamics changes. This means that subjects addressed by the activity attribute new senses to it. For instance, Tavares et al. (2009) showed activity reorganization and complexification when the actions and operations acquire different senses during untypical pediatric classes in a hospital situation.

Mattos el al. (2008; see also Tavares et al., 2009; Rodrigues, 2009) looked at the structure of the activity, taking account of its complex nature. From this point of view, the unit of analysis may not be static, but depend on how object's complex structure is observed. Then, operations may be seen as actions and actions as activities. Therefore, in this research activity is considered a complex system.

If we consider a regular and a hospital class context, planning has different meanings. For instance, context dynamics time-scales are completely different in hospital classes than regular ones. During a hospital class, the operations that constitute the action of planning, joined with other actions inside the activity being taught are constantly changing. The action of planning is characterized by this not becoming a previous action to teaching, but a dynamic action, taking place after and during the class. From this point of view, the activity of teaching is reorganized within these "more specific" contexts (Tavares et al., 2009).

In a recent paper, Engeström & Sannino (2010) in building the Activity Theory background, highlighted several other aspects, as inner contradiction (Engeström, 1987). This allows us look at transformations in an activity from another perspective.

> Activity theory is a dialectical theory, and the dialectical concept of contradiction plays a crucial part in it. Following Il'enkov (1977, 1982), the theory of expansive learning sees contradictions as historically evolving tensions that can be detected and dealt with in real activity systems. In capitalism, the pervasive primary contradiction between use value and exchange value is inherent to every commodity, and all spheres of life are subject to commoditization. This pervasive primary contradiction takes its specific shape and acquires its particular contents differently in every historical phase and every activity system. Most importantly, contradictions are the driving force of transformation. The object of an activity is always internally contradictory. It is these internal contradictions that make the object a moving, motivating and future-generating target. Expansive learning requires articulation and practical engagement with inner contradictions of the learners' activity system (Engeström & Sannino, 2010 pp. 4-5).

This important aspect – inner contradiction of an activity – is reflected, in our research, with the tension between careful planning and the necessary improvisation. This apparent dichotomy in the practice of teaching drives the activity to be the subject of change and transformation.

Case Study

An experimental activity has a wide-range of applications and possibilities as a teaching-learning strategy. In physics, we include experimental activity, from a simple demonstration of a phenomenon verifying a theory, to the manipulation of sophisticated statistical procedures to data processing and posterior interpretation. In the case studied, the experimental activity was prepared by the teacher, emphasizing a simulation of an investigative situation in order that students could reflect about modelling phenomena as a scientific practice (Hofstein & Lunetta, 2004).

Our case study is about a teacher that developed an experimental task for students at age of 14-15 years old in a private Brazilian high school. All students were in the beginning of the first year of the three years Brazilian secondary level. The teacher planned an activity to investigate what are the time functional dependent variables for a simple pendulum in order to obtain the mathematical expression of the pendulum period. The task was done in three different class-groups of students (A, B and C) each one with 25 students. And the same didactic sequence was used by the teacher in all classrooms. Each class-group had two meeting to develop the task in two lessons. The first lesson occurred in the laboratory where students measured the relation of period with different pendulum variables, and the second lesson was in a regular classroom to analyze data obtained in the laboratory and to propose an explicative model to the simple pendulum.

The two lessons were organized in three stages: *i*) initial guidelines explaining the phenomenon and what measures must be done, *ii*) data acquisition (1st class); and *iii*) discussion of the proposed models by the teacher (2nd class). The teacher organized the students of each class-group in smaller groups (4 to 6 students) attributing to them the responsibility to verify, each one, the time dependency of a different variable. The teacher provided all groups with an experimental kit with which to take all necessary measurements. During the second class meeting, the teacher discussed the procedures adopted by each group and showed aspects of data outcomes, pointing out the importance of functional concepts and the presenting of data in the form of tables and charts.

Methodology

This qualitative research (Bogda & Biklen, 1994; Erickson, 1998, Roth, 2005), considered specific methods to obtain data allowed conclusions in specific contexts. The research method is focused on teacher's performance and not on an evaluation of teaching methodology, nor the relevance of the specific content to the high school level.

The complete lesson plan was carried out in three different classrooms of the first year of high school, as pointed earlier - A, B and C, and had duration of 65 minutes. Data collection was obtained through panoramic video recordings of the classrooms during the lessons, researchers' field notes and a written questionnaire answered by the teacher. The researchers followed steps of the teacher's class planning, for instance, the preparation of guidelines for the experimental task, they were present during all lessons, and they interviewed teacher at the end of the whole process. Two researchers accompanied the intervention. One was responsible for operating the video camera while the other made the field notes. From the ethnographic point of view, the researchers made an effort to uttermost characterize the lived situation at the classroom without interfering with the lessons. The researchers stayed at the backside of the classroom and they interacted with the students only when requested. The students were not discommoded with the researchers' presence since this kind of research – observation and video recording of classes – was usual at this school. The school coordination team uses to video record teachers' activities to posterior discussions about their classes. The interview with the teacher had the objective to recover aspects of his expectations during the lessons at classroom. To recuperate those aspects allows looking for indicatives of how teacher self-evaluate his performance, i.e., how he became conscious of his failures and successes during and after the application of the class plan.

Data Analysis

Various elements characterizing the physics class can be understood as a system of activities, for instance, group work, experimentation, planning, lesson plan, class council, etc, and are factors ranging from the particularities of the physics class to the school as a whole, to social dynamics. Planning, seen as an activity, is composed of several actions and operations that are coordinated with each other. In this sense, the action to prepare the laboratory aims to organize and anticipate the experimental procedures to be performed. This action has several operations, including the operation of separating the materials and instruments for the experiment.

When planning is considered as an experimental assignment, we can highlight it as an action to elaborate the experimental guide. To implement this action, the teacher has to articulate the operations students need to perform in data collection. Among these operations, we identify the handling of the measuring instruments, annotation of data, the construction of tables and graphics and so on.

We observed that the teacher's initial plan was to separate students into small groups who during the class alternate their tasks in order to each group measure all variables, an action that shows some complexity. Thus, all students would experience all experimental situations, demanding them to observe and manipulate all variables. However, between two classes the teacher recognised during informal conversation with the researchers the limitations of time and space. He thus changed the experimental dynamics in the next class requesting each group to evaluate just one variable and share their results at the end of the class, so as to consolidate the experience as a whole.

Thus the teacher planned a distribution of tasks he considered appropriate, proposing an initial introduction, the experience implementation and the closure. While carrying out his plan in classrooms A, B and C (successively), the teacher changed the time reserved for each part of the lesson. This gives us evidence that planning is constantly built and rebuilt. Teachers ask, evaluate and redo their actions for the activity, acknowledging the need for planning across all stages of the course. In other words, we understand that the prior planning and the on-line planning are related dialectically, one serves as the basis for the development of the other.

In addition to the actions to prepare the laboratory and the experimental guide, we can identify other actions that structure the experimental activity planned by the teacher. For instance, during the initial dialogue with students, at the very beginning of the first lesson, the teacher introduces important phenomenon variables to be observed. He also organizes students' data collection and presentation of this at the end of the activity. This basic architecture of Leontiev's activity is essential for us to understand the coordination of actions and operations. By not considering the experimental activity as homogeneous, we realize that it is permeated by several other elements. For instance, we present transcribed data in which we observe how the teacher operationalizes the action of introducing the variables for the phenomenon being observed. Students are identified by the same letter as his/her classroom, followed by a number:

Data - Start class (laboratory) of the classroom A
T: *... and what is a pendulum?*
Students*: It is a weight balancing. It is a kinetic energy about energy (...).*
T: *What is a pendulum? Do you need your book? It's here in my hand, you don't need your book now. What is a pendulum for you S1?*
A1: *Something that is balancing.*
T: *It is something that is balancing. The question we will answer today is: Why and how does it balance?*
A1: *Because it has energy (...) energy of movement.*
T: *It is composed of some parts and we will study its parts. For instance, it has a ball*

here that is its mass. It has a little wire. If I, for instance, reduce the size of the wire, what happens with the balancing of the wire?

A3: *Faster.*

A1: *larger, more slowly.*

A4: *The time of oscillation is (...)*

T: *If we substitute that mass for a bowling ball (teacher gesticulates the movement of the pendulum)*

A5: *It will be the same.*

T: *Those things we will study in the class today, I don't want to advance any answer now, but there are questions that we must do. Look at the blackboard now [shows a sportsman's video jumping of Bungee Jump]. What is it?*

Students: Bungee Jump. A pendulum.

T: *Is this a "dude" falling or a pendulum?*

A6: *It is a pendulum of people.*

A4: *It is a human pendulum.*

T: *It is a human pendulum. You jump from a mountain, from a bridge, like this and oscillate like a pendulum. Why does he balance? The speed he balances, the time needed to go and to return, it is what we will research today.*

A1: *It depends - on the mass, on the time.*

T: *It depends on the mass. On what else does it depend?*

A4: *On the height.*

T: *On the height. If that pendulum was high in the mountains, or was here below, will it change? There are some types of pendulum [showing photos of different oscillatory motion]. This is the famous pendulum of Foucault, with him we discovered ... is evidence that the Earth is rotating, how do we see it through a pendulum? Here there is energy pendulums, to measure if persons have good aura, to see if the person is good or evil, to predict his/her future, mystic pendulums. There is a guy balancing. All of them are in a pendulum motion. Which is the objective of the experience? Look at the table on page one [referring to the text book]. Everybody should fill in the table and for that there are two things to do. One is the height of the pendulum and the other is to measure the period of the pendulum. The period of a pendulum is that here, the time a pendulum uses to go and to return to the same place. How long does it need? Then a person takes a stopwatch and the other holds the pendulum. Then activate the stopwatch when the ball is released, then stop it when the ball comes back to the same place. The problem is that if you do it just for an oscillation the measures change a lot from person to person. Thus we will do it for 10 oscillations, you should counts each round trips 10 times.*

As shown in the above transcript, the teacher starts the dialogue with a key question <<What is a pendulum?>> This question has the function to start the dialogue questioning the students' knowledge. In all three lab classes, this key question is repeated. In our analysis this is an important marker. Between this first question and the beginning of the teacher's monologue the teacher organises metaphors, examples and other issues that he uses to conduct the dialogue. In the second transcription below, the teacher starts with the same key question <<What is this?>> holding the stopwatch on a cord and letting it swing. Again the dialogue begins with the response of the students. The similarities and differences between these two transcripts can provide information about the reorganization of the planning of the teacher in the class.

Data - Start class (laboratory) of the classroom B
T: *The question is, in the activity today: what is that here?*
Students*: A stopwatch. A pendulum.*
T: *A stopwatch. Many people spoke pendulum, but I ask: what is a pendulum?*
Students: A thing that balances. Something that balances with the angle.
T: *Is that guy there a pendulum? Is he a pendulum? (The teacher shows a sportsman's video jumping of Bungee Jump)*
B1: *It is, that guy is a pendulum.*
T: *If that guy is a pendulum, what is a pendulum?*
Students: Laughter.
B2: *It is a motion caused by the gravity.*
T: *It is a motion caused by the gravity. This is a good definition, it is a movement caused by the gravity. If there is no gravity, would I pull the pendulum here (teacher holds the ball in certain inclination), turn off the gravity and let it free, what happens? (Teacher gesticulates the movement of the pendulum)*
B2: *it stays there.*
T: *I would release it but it should stop, because there is no gravity. Then we already know that it is a movement caused by the gravity. This is if we consider ourselves as Newtonians who believe in gravity. Good. The biggest question now is the following: does the gravity influences the pendulum? And if I take a higher wire and release [the pendulum], how does this wire influence the pendulum [motion]? And if I changed that ball for an elephant? How do the elephant would influence the pendulum? If I made the pendulum oscillate like this and like that (gesticulate showing larger and smaller oscillation angles for the pendulum motion)? Would it change things? We will study that change. What happens if I change the mass for a bigger mass, if I stretch out the wire making it small or short, or if I change the oscillation angle? Starting from those decisions, we will build mathematical formulas, based on what we decide to be relevant or not. Here are some types of pendulum [teacher presents and quickly comments on three examples of pendulums, as he did in the previous class]. What I want you to measure, the fundamental objective of our experience, is to measure the period of a pendulum (...). How do I measure the time of an oscillation, a round trip? The problem when you measure the time to go and to return, it goes and turn, sometimes you don't know if it stops here, if it stops here or there (indicating three different positions to the pendulum). In other words, you have a lot of uncertainty in your time measures. So what we will do is to measure the time of 10 oscillations. One, two, three, four, when it has ten oscillations you stop the stopwatch ... because measuring just one oscillation gives errors. But do those two things, count one and count 10. Then we will fill out the table with ten values of time that you counted. Each group will be in charge of a measure. Another thing, you need to know the length of the wire of your pendulum. You hang the wire on the wall and ... measured the size of your wire here [showing the center of the pendulum ball]. It is that I want you to measure as L in centimeters. Is it also needed to know the mass of the balls, I put 100g, 200g, 300g. You can use a balance to measure the mass ... After all this, you will take millimeter paper sheets, but not today I don't know if we*

will have time to do it today. With your data in tables, we will build graphs and later we will look at the graphs and talk about ... and we will build mathematical models starting from those comparisons [of graphs]

In the first transcript, the teacher devotes about 20 turns in a dialogue with students. On the other hand, in the second transcription, the teacher devotes only half of the turns. This difference was not caused by a lack of interesting elements, or any other aspect restricted to the speech of students. From our point of view, this difference comes from the teacher's reorganization of the planning time. Faced with student demands, he change the distribution of time, introducing some rules (and hints) earlier, impeding a dialogical construction of this necessary elements to achieve task resolution. He did it mainly to save time.

An evidence of this is that in the first lesson (classroom A) the teacher cannot complete all the scheduled tasks. This fact warned the teacher to change the schedule in the second classroom (B). The teacher tried to save time from the very beginning of the discussion to the end of the lesson, in order to complete everything he had programmed. Several times the teacher complains about the lack of time to perform the experimental task. In other words, this tendency to make shorter a dialogical interaction in the last classrooms (B and C) is related to a teacher's choice to organize the schedule.

Another important evidence is the amount of new information available to the second class (classroom B). When changing from classroom A to B, the teacher notices the need to give more precise information about how to handle the experimental apparatus. This reduces the dialogue with the students allowing time to insert a range of information on the operation instruments. At the end of the first laboratory class, the teacher found students had problems to conduct the data collection. Students had difficulties in handling the available instruments on the lab tables. The teacher expected that operating tools such as protractor, ruler, stopwatch and balance should already be operationalized by the students. However, when faced with the contradiction of his expectation, the teacher evaluates and remakes the planning for the next class (in another classroom), restructuring the activity. More specifically, the teacher includes some explanations on the use of instruments. This choice made instrument manipulation change its hierarchy in the activity, from first considered as an operation, to now as an action demanding consciousness of the students to deal with the instruments.

The initial expectation of the teacher could be observed during the class. He intended to build a simple pendulum equation. However, in the second lesson (classroom A), students faced problems in handling quadratic equations, an content expected to be known by those students. Again, the teacher had to evaluate and reorganize the planning for the second class in classroom B, where he explained, in detail, the quadratic equation and was surprised with the ability of this class. Again the teacher had to rearrange his actions, restructuring plans, but in a new time scale, during the lesson.

At last, to implement the activity, the teacher found an appropriate temporal distribution of the tasks during the lesson for classroom C.

Conclusion

The analysis indicates that teacher's planning before lessons are based on what he is expecting to be operated by students. When expectations confront live classroom contradictions, this demands changes in various time scales. It means transforming the activity and demanding adaptations to a new context.

We can also spot that Activity Theory could model the hierarchical dynamics that appear during the dialogical interactions. This dynamic presents turbulences that implicates in a change of the hierarchical levels of operations and actions that compose the activity. The teacher is required to deal with turbulences that show when his plans are tested in a real interaction with students, whose expectations not always corresponding to those of the teacher.

Moreover, we can conclude that it is important teachers know the complex dynamics in which classroom are immersed and how to deal with the frustration of failed expectations. This adaptability or improvisation could be considered only when the teacher comes to a dialogical position (Krauss et al., 1995) which includes the students and the dialogical dynamics into his planning.

Finally, this work provides important elements to rethink the teacher's formation. The extension of the planning concept collaborates for pre-service teachers the need to include dialogue as one of the most important educational tools in dealing with classroom decision making. Only by facing planning as an operation that must became an action when contradictions between teacher's expectations and the actual class situation, ensures teachers have chance to be successful in achieving fruitful and meaningful science education.

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