

The Teacher's Movements Toward the Use of Science Communication in the Classroom: A Model from the Activity Theory

Guilherme da Silva Lima  Brazil

Marcelo Giordan  Brazil

The science communication (SC) is one of the means that the science teacher can use to foster teaching activities. However, it is noteworthy that the SC is produced to meet the communications needs between the science culture and the society, and the school is not a presumed address to science communication. Thus, in order for science teachers to use SC in teaching activities, they need to appropriate it and adapt it to educational proposes. This paper presents a model that aims to understand the teacher's movements for using science communication in the classroom. Grounded on the activity theory, it analyzes from the system of activities approach how the teacher interacts with the SC. The results highlight four systems of activities in which science teachers act, their interactions and unfoldings, which are classified in three hierarchical levels.

Keywords: science communication; activity theory; science teaching; teacher training.

Introduction

The science teacher uses a variety of resources and techniques to achieve educational goals. Among the resources, the textbook is probably the most frequent. However, there are several studies that report the use of experimental activities, films, music and Science Communication (SC) (Martins, Nascimento, & Abreu, 2004; Zômpeiro, & Laburú, 2012; Ernst, Silveira, & Albarrancín, 2016; Dias, & Messeder, 2017). Some of these resources, however, are not elaborated for educational purposes, which can lead to difficulties in planning and developing teaching activities.

The interaction of the science teacher with SC is the focus of this paper, especially considering that SC is often approached in science teaching (Lima & Giordan, 2017a). However, it is worth mentioning that SC differs from textbooks, even though SC is predominantly a written material. While the textbook is produced to attend and to be adapted to teaching purposes, SC is not. SC reaches the classroom through different paths, based on cultural practices that are predominantly determined by their interaction with the social communication.

Social communication is SC's original locus. SC, in turn, aims to establish interactions between the scientific culture and a certain audience of society, which is not broad and general. The reports, interviews, television programs etc. that we classify as SC aim to reach a specific audience. There is SC for children, average citizen, people that

have a greater interaction or approximation with the scientific culture and so forth. But SC is an instrument produced by the social communication, which intermediates the interaction of individuals with the scientific culture.

The fact that SC has its origin in social communication does not eliminate its relationship with education. Gouvea et al. (2014, p. 20¹) points that the newspaper “is a document, source of information, an object of the material culture of Modernity, with which it is modified; and as an object of the culture it becomes a pedagogical tool, because it points to possibilities of educating our vision about the world”. This possibility of transforming a newspaper into a pedagogical tool can be applied to SC, being both instruments of social communication capable of circulating through all the spheres of human activity, from which we highlight social communication and education.

When we focus on the use of SC for educational purposes, various characteristics of such resource and of its consumption are altered. The student, for example, does not interpret SC as a resource with an exclusive origin in social communication, but with its origin also in school (Lima & Giordan, 2017a), since this is the institution where he/she interacts with SC. When SC is approached in that context, it assumes specific teaching purposes and can contribute: to develop a concept or the history of science, to promote a debate etc. (Lima & Giordan, 2017a). In short, the use of SC in formal education requires the restructuring of educational activities associated with the appropriation² of SC.

When we think of a reading activity, the textbook demands a planning and a structure different from what the reading of a SC report requires. Pagliarini and Almeida (2016, p. 313-314) contribute to such discussion by pointing that:

the approach of physics contents through the reading [of a SC support] brought students closer to scientific issues with a language that is often more accessible than the excessive mathematical formalization found in the curriculum of such subject.

We acknowledge that the authors do not specifically study the differences between the reading of a textbook and a SC. However, we can expand their statement, since excessive mathematical formalization is also often found in textbooks. Therefore, we understand that SC texts can articulate distinct aspects from those commonly addressed by textbooks, because of their narrative structure or even because of relations that are established by concepts, stories or practices that are pertinent to the scientific culture.

Moreira et al. (2017) also contribute to such discussion by developing a study on the relationship between a didactic text and a Science-Technology-Society (STS) approach. The authors claim that their

analysis showed the intertextuality of the science education research in the constitution of the DB [didactic book] analyzed, considering choices based on (i) the dialogue with the student, (ii) the construction of knowledge as a process historically situated in opposition to knowledge as being final and true, (iii) the reflection as a way of learning

1 All translation of this paper are ours.

2 The understanding of the concept of appropriation used in this paper corresponds to the contributions of Wertsch (1999), who establishes that the appropriation of a cultural tool occurs through its arbitrary use by the individual.

(Moreira, Pereira, & Martins, 2017, p.7).

We cannot extend those characteristics of textbooks to SC because its main purpose is not the scientific education. However, similar characteristics can also be found in SC, such as the dialogue with the public and the historically situated approach. Nevertheless, the foundations of the narratives found in the textbook and in the SC are distinct, especially due to the reasons that sustain the production of these resources. In that sense, SC does not establish a dialogue with students, but with consumers of newspapers, magazines, blogs, digital channels, television programs, film productions etc. Therefore, to adapt SC to formal teaching situations is a basic requirement to insert it in the classroom and it is usually done by the teacher.

The focus of this paper is the movement that the teacher does to appropriate a resource produced by the social communication sphere and to use it in the educational one. Although we recognize that SC has inherent educational characteristics, these are not linked to formal education. Therefore, there is at least one movement that should be done: to transform an activity from the informal domain into the formal one.

During the process of appropriation, there are several moments in which the teacher interacts with the SC. The origin of such appropriation has its basis on the consumption of cultural goods produced by the social communication; it is focused on the teaching goals of a certain area of knowledge. In this article, we aim to discuss, present and defend a model to understand the movement that teachers do to use SC resources in the classroom. To do so, the activity theory was our theoretical basis.

Considerations about the activity theory

Vigotski was responsible for initiating the studies about human development based on the dialectical and historical materialism. Vigotski's main results showed that the human being is a product of both biological evolution and cultural development.

The fundamental concepts he proposed can be structured in two axes that are the base for the development of that theoretical current, which are: the relationship between the human being and the world mediated by instruments and the social division of labor.

In reply to the question "What is the humankind?", Vigotski (2000, p. 33) highlights: "For us it is the social personality = the set of social relations embodied in the individual (psychological functions built by the social structure)". Thus, the humankind is a product of the internalization of social relations and, at the same time, it dialectically relates to the very structure of society, that is, it constitutes the social. Hence, Vigotski defends the dialectical relationship between the individual and the society: if the humankind is a set of internalized social relations, the social is the organization of individuals.

Pino (2000) synthesizes what is the meaning of the term social in Vigotski:

First, the social is a general category that applies to a set of phenomena which, in the animal world as well as in the human world, involve different forms of organization of the individuals [emphasis added]. Second, in both animal and human world, the social is an "added value" to the biological, in whatever way it emerges (p. 60).

In turn:

[...] social relations constitute a complex system of social positions and roles associated with these positions that define how social actors place themselves in relation to each other within a given society and what are the expectations of conduct associated with them (Pino, 2000, p. 64).

Vigotski is based on the social division of labor when referring to different actors and social roles. Pino (2000, p. 62) explains: “the way in which men produce/reproduce, through their social and physical conditions of existence and the social work, represents their own way of life, which reflects more precisely what they are”.

In short, Vigotski points that “a person’s psychological nature is the set of social relations that were transferred to the inside and became functions of the personality and forms of its structure” (Vigotski, 2000, p. 27). Thus, Vigotski considers that the human being’s psychological development occurs through the internalization of social relations.

Such characteristics constitute the human being and present elements that refer to the importance of mediation, considering the constitution of an individual is not a fact by itself, but determined by the social environment. That is, even the human being’s development is mediated and, therefore, it depends on external elements that are responsible for the development of higher psychological functions and personality.

To consider mediation as the central foundation of a general theory of human development, as it happens with the activity theory that has a historical-cultural base, does not only imply that the constitution of the human being is mediated. In examining Marx’s and Engels’ works, Leontiev (2004) argues that human work is social and produced through tools, which differentiates human beings from other animals. For Leontiev (2004, p. 81): “However complex the ‘instrumental’ activity of animals may be, it will never have the nature of a social process, it is not collectively made, and it does not determine the relations of communication between the beings that make it”. Thus, work is essentially collective, and it is a human activity on the natural and/or cultural³ world, determined by and directed to society.

Human work, on the other hand, is an activity originally social, based on the cooperation among individuals that supposes a technical, or even embryonic division of the functions of work; thus, work is an action on nature, connecting the participants to each other, mediating their communication (Leontiev, 2004, 81).

Based on that, we understand that the human interaction with the world occurs through both mediating elements, which can be understood as cultural tools, and activities that constitute the collective work on nature and culture.

Among other neo-Vigotskians, Engeström (2015) excelled at understanding the activity with a mediating structure and in its social and systematic development. In summary, Engeström expanded Vigotski’s mediational representation scheme (Figure 1), establishing the relationship between Subject, Instrument and Object to include the

³ We broadened the meaning of the concept of work presented by Leontiev to include the activities about the human culture.

macro-social relations of the community that performs the activity.

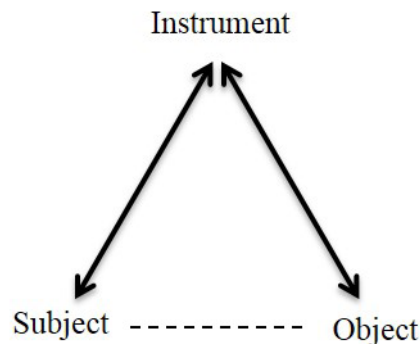


Figure 1. Mediation in Vigotski. Adapted from “Psicologia concreta do homem”, by L. S. Vigotski, 2000, p. 29

For that, Engeström (2015) proposed the concept of activity system. In addition to the mediating elements from Vigotski’s scheme, Engeström inserts in the activity system the social division of labor, the community and the rules that govern the activities, which had already been discussed by Leontiev. To synthesize his proposal, Engeström (2001) suggests a diagram that correlates the elements of the activity system (figure 2).

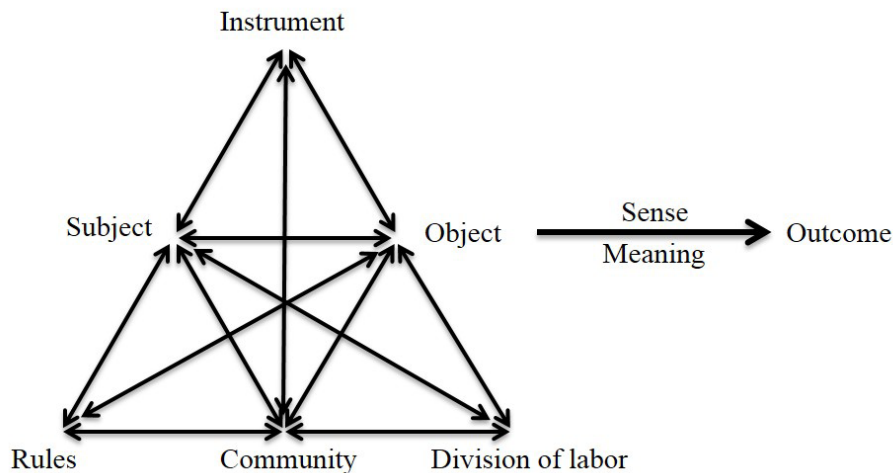


Figure 2. The activity system model. Adapted from “Expansive learning at work: toward an activity theoretical reconceptualization”, by Y. Engeström, 2001, p. 135.

Through Engeström’s model (2015) it is possible to correlate the individual actions in the context of collective activities, governed by collective rules, agreed by the community and by the social division of labor. The model also allows us to analyze and understand the different relationships among the activity’s elements. Through several correlational triangles, it amplifies the interactions by inserting characteristically social elements into the forms of human convivence. We understand that the scheme proposed by Engeström represents a good contribution to the activity theory, since it synthesizes and organizes in a schematic and relational way fundamental principles that Vigotski and Leontiev approach.

To interpret that model, we can emphasize the ‘subject - community - object’ triangle and suggest that the interaction between the subject and the object is also determined by the community to which the subject belongs. As an example, we can highlight the relation that the teacher has with the school scientific knowledge and the relation that a school principal has with the same object. These are fundamentally different interactions, since the subjects’ community and their social functions vary. While the relations between teacher and knowledge are predominantly at the level of teaching practices, the principal’s ones are centered on the curriculum development and the school’s pedagogical project. Both relationships are in distinct activity systems and, therefore, have different social rules and social divisions of labor.

Engeström (2001) also emphasizes that the activities are not isolated in society, thus, activity systems can interact. The activities can relate to each other because of the different elements that compose them, but it is important to draw attention to their sharing of objects. When we focus on SC, we can think of different activities with the same objects. This occurs in the case of consumption and use of SC in teaching contexts, in which case the shared object is the scientific, mobilized for several reasons.

Engeström (2001) proposes another infographic (figure 3) to synthesize the interactions between the activity systems:

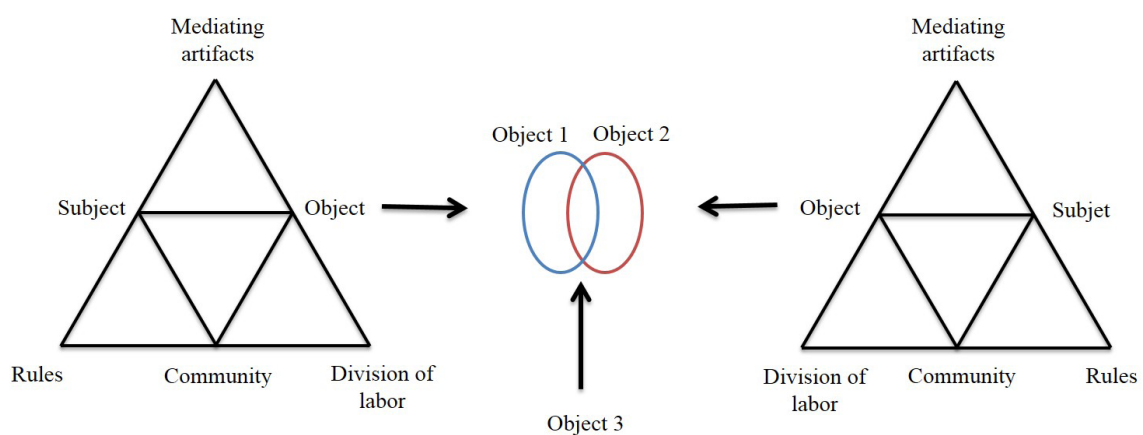


Figure 3. Interaction between activity systems. Adapted from “Expansive learning at work: toward an activity theoretical reconceptualization”, by Y. Engeström, 2001, p. 136

For him, the interrelation between the activity systems places their objects in contact, which collectively produces a new object through contradictions⁴. We emphasize that in both activity systems the ways in which subjects interact with objects depend on the activities being performed, even though they are similar objects. Therefore, when

⁴ In this case, the meaning of the term corresponds to that of the Marxist tradition. According to Bottomore (1988, p. 79-80), “Although the concept can be used as a metaphor for any kind of dissonance, divergence, opposition or tension, it assumes a certain meaning in the case of human action (or, more usually, of any goal-oriented action), specifying any situation that allows the fulfillment of an end only at the expense of another, that is, a connection or coercion”. We emphasize that the concept of contradiction is central in the Marxist dialectics and to deepen it, we recommend reading Bottomore (1988), as well as Marx’s originals.

there are interactions between activity systems, such interactions occur amid various contradictions, conflicts and tensions between the activity's motives and objects.

Engeström's contributions (2001; 2015) on the activity theory are considered to interpret the teacher's movements when mobilizing SC in formal teaching situations. Therefore, our argument is based on the activities that the teacher conducts in the different social positions that he/she occupies when he/she interacts with SC or appropriates it. Although there may be several paths to approach SC in that context, we have considered situations in which the teacher assumes the position of a SC consumer, representing any other person from the audience of this type of communication. Given our research is focused on teaching activities, the impacts of SC in the students' learning are not included in the model proposed to interpret the teaching activity systems.

We have not only considered SC in the perspective of its consumption, but also in terms of the activities of its production. That is because scientific education, which is the teacher's main purpose when mobilizing SC, occurs between tense and contradictory relations that permeate such activities. To specify and interpret teaching practices, we examined two other systems that connect to constitute them: teaching planning and classroom performance. Thus, based on the activity theory, we proposed an approach to understand the use of SC in formal education, considering it a result of the interactions between activity systems of which the teacher is an agent.

Activity systems in the teacher's movements for SC mediation in teaching contexts

To understand the teacher's movements for the use of SC in teaching contexts, we present the main activities associated with SC and that allow its use in the classroom, namely: SC Consumption, Scientific Education, Teaching Planning with the Use of SC in the Classroom. We would like to highlight the fact that any communicative process is produced by socially organized individuals (Bakhtin, 2009) and, therefore, to interpret it from only one of its poles (Consumption) would induce us to misunderstandings. In that sense, we understand it is essential to consider the activity of SC production even if it does not have the teacher as the activity's subject. The SC Consumption is one of the motives that sustain its activity of production, creating a dialectical relationship between one activity and another.

The SC Production activity system can be represented as in the Figure 4.

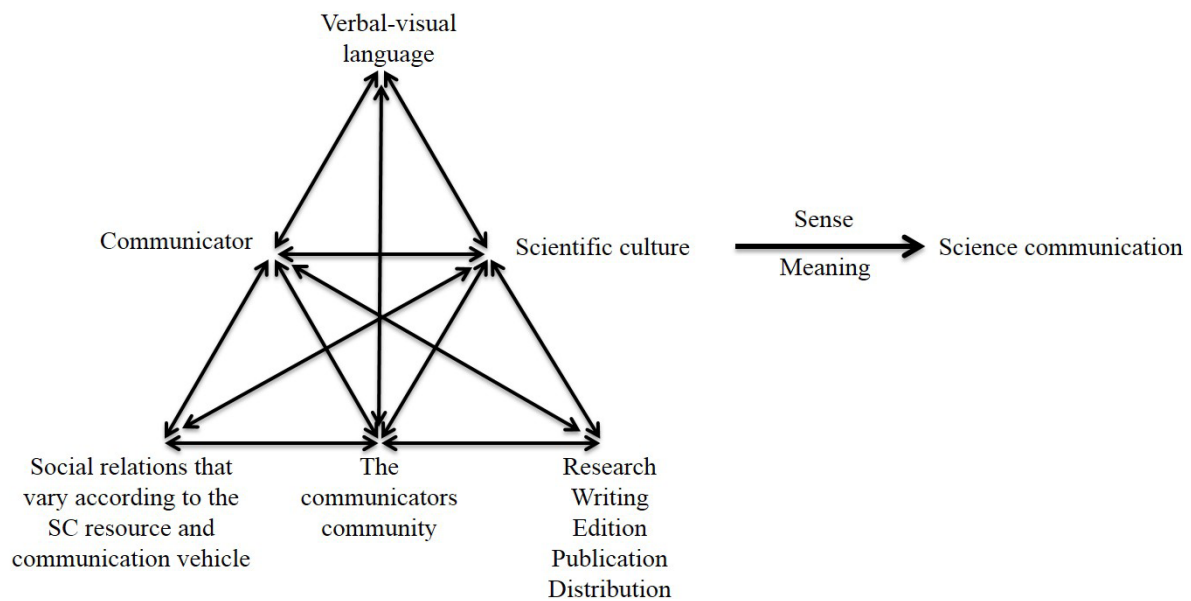


Figure 4. Science Communication Production activity systems

It is possible to interpret the various nuances of SC production if it is understood as the product of an activity system. The communicator is the subject whose role is to represent the scientific culture in the activity system, regardless his/her social position (journalist, scientist or teacher). Regarding the mediating instrument, we have considered the verbal-visual language as presented by Grillo (2009), which is a frequent symbolic form for SC Production. The object of the SC production system (figure 4) is the scientific culture itself, since it is a human enterprise produced through communicational processes to communicate and insert new members in that culture. The division of labor occurs through actions conducted toward the SC Production and includes research, writing, edition, publication, distribution, among others. We emphasize that the division of labor varies according to the resource used, which means that the division of labor to produce an article in scientific journalism is different from the one that is necessary to produce an audiovisual documentary. We consider that the community responsible for the SC Production is the communicators community and not just the scientific one, because not all its members necessarily participate in the internal processes of Science Production, such as journalists. Finally, the rules that govern SC Production refer to the social relations among the subjects and vary according to the communication vehicle and media. The rules of the scientific journalism's social relations are not homogeneous, since, for example, an anchor presenting an audiovisual SC report involves different rules from a written article in a weekly journal. Regarding these rules, it is worth mentioning the social relations established in the SC Production, which are loaded with ideological positions in relation to objects and products of collective work.

We have previously argued that it is not possible to understand SC Production (Figure 4) from an isolated perspective, regarding its structure and constituent elements,

since its target audiences or recipients exert constraints on the SC enunciative productions. Thus, to interpret the SC Production, it is necessary to understand the consumption of this cultural good. In the current study, we will focus in such consumption by the teacher.

To guide this interpretation, we have positioned the teacher as the subject of the SC consumption activity (Figure 5). Although he/she is not the only one to consume SC, he is the promoting agent when SC is inserted in the classroom.

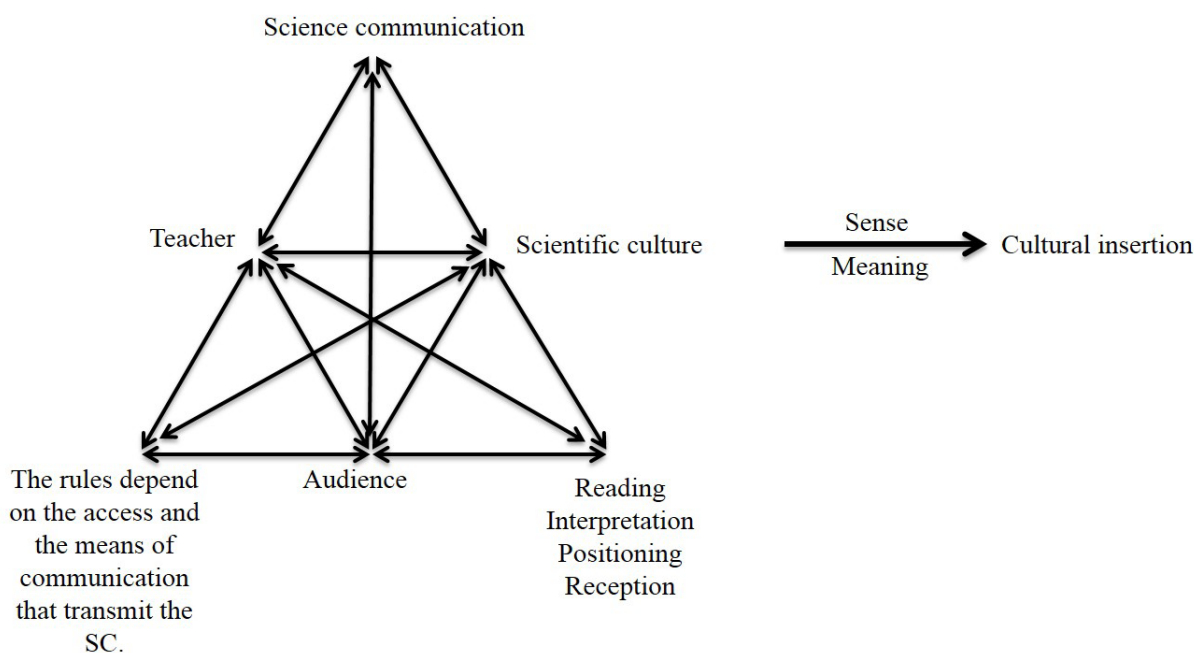


Figure 5. Scientific Communication Consumption activity systems

The maintenance of the scientific culture as the object of the activity is determinant for the proposition of the model. The activity systems that we classified as SC Production (Figure 4) and Consumption (Figure 5) are related through contradictions, disputes and tensions articulated by the motives that generate the activities, as well as by the subjects who perform them and the social groups that they represent. Such tensions have as their vertex the scientific culture, which is the object of both activities. It is important to emphasize that despite the maintenance of the activity systems' object, its forms of interaction and consequently its nature are different in the set of activities. If, on the one hand, SC Production (Figure 4) relates to scientific culture through scientific practices and products, on the other hand, the Consumption activity is related to scientific culture. This relation occurs through SC, which constitutes the scientific culture, like the scientific practices and products. The relations between the subject and the scientific culture in the SC Consumption activity system (Figure 5) are predominantly mediated by SC media. This is a relation that we consider to be of second order, unlike the relations in the Production activity, which are of first order. In the case of SC Production (Figure 4), there is a relationship between the activity's subject (communicator) and the

activity's Object (scientific culture); SC is produced from such relation. In the case of Consumption, the interaction of the activity's Subject (teacher) with the activity's Object (scientific culture) occurs through the SC itself, that is, it depends on a resource that contains socio-ideological positions and orientations about the object in question. This is what we understand as a second order interaction: an interaction that is mediated by a product generated by an activity of adjacent production, without which it would be an activity impossible to be performed.

We emphasize, however, that in the relationship between subject (consumer) and object (scientific culture) there are several tensions produced by the creation spheres that sustain the activity systems. These tensions can be maintained in the relations between the SC production system (Figure 4) and the system that establishes the use of SC in the classroom⁵ (Figure 9). However, when we focus on the teacher's movements toward the use of SC in teaching situations, that new relationship will be more complex because of the consumption context, which inserts elements of formal education in the interaction between the activity systems.

In addition to the scientific culture, it is pertinent to highlight the correlation between the mediational instruments of the two systems. The verbo-visual language is present in both the SC Production system (Figure 4) and the SC Consumption systems (Figure 5). However, in the Consumption, it is already incorporated into the SC resource. Therefore, being already in the SC Consumption activity (Figure 5), it becomes the subject's mediational instrument to develop social practices from the scope of scientific culture. The transformation of SC into a mediational instrument becomes more evident when we focus on the main motivation of its consumption, in the context of the current research: the insertion of new subjects in the school practices of the scientific culture.

The division of labor in the activities of Consumption considers a variety of actions, from the access of SC until its reading and position that is assumed when the issue it addresses is faced. The SC Consumption community is, in turn, the audience, the target recipients⁶, who may be teachers or even students, depending on how the product of scientific culture is mobilized. Finally, the rules, which are proper to the Consumption and choice of SC, can be delimited by the social groups of which the readers are part, as well as by the access and reach of the publication. The Consumption activity generates the active subjects' cultural insertion, since it allows its consumers to understand, position and create values regarding the scientific culture, which is the activity's object. Thus, through the SC instrument, the audience interacts with aspects of the scientific culture.

Another fundamental activity to understand the use of SC in science teaching contexts is the school education. Education can be considered as a complex system of

5 One of the main tensions refers to the coercion of the Capital about social communication. Often, the approach of a certain theme or the bias adopted by a science communicator is determined by interests of the publishing industry or financial conglomerates.

6 We emphasize that because of the asynchrony of communication existent in a large part of SC, its real recipients may differ from those who would be expected in the SC production process (Lima, & Giordan, 2017b).

activities multifaceted and concretized by various agents. We have delimited its elements considering our research focus. Thus, we limited our analysis to the characteristics of Science Teaching and its conditions of production. Again, we proposed the scientific culture as the object of this activity system, which is the main referent of Science Teaching.

In Science Education, language is the main mediational instrument between teacher, knowledge and students. It should be noted that language can be expressed in several modes of communication (Kress, 2010) and through various media. The textbook is a widely known and used support in teaching situations, but we highlight SC as a privileged support for science teaching. In general, science teachers mobilize multiple cultural tools to promote science education. It is important to emphasize that cultural tools necessarily pass through the teacher's filter, since he/she is the one who chooses them to approach a certain content. Therefore, the use of SC in teaching situations is determined by the SC Consumption relationships established by the teacher.

Scientific Education has a broad spectrum of subjects in the school community (teachers, principals, coordinators, students, etc.) who work in activity systems. The division of labor is distributed among activities of administration, coordination, teaching, evaluation, among others that are governed by curricula, didactic contract, working conditions etc.

It is fundamental to understand Scientific Education as an activity system, since it is one of the determining factors for the use of SC in teaching situations. The Scientific Education exert constraints on the definition of contents, as well as on the approaches toward the use of SC in the classroom. Such constraints are articulated through the activity's rules and mediational instruments. It is worth mentioning that, according to the Constitution of the Federative Republic of Brazil of 1988, the main purposes of education are the development of the person, his/her training for the exercise of citizenship and his/her qualification for work, reasons that we can extend to Scientific Education. When we focus such reflection on the teaching activity, we find that the Consumption and Scientific Education activity systems (Figures 5 and 6) are put in contact and, in turn, intensify the disputes between their objects (scientific culture). That way, we defend that the scientific culture is an object shared between the Consumption (figure 5) and Scientific Education activity system (Figure 6). Such sharing occurs amid the contradictions and negotiations the teacher conducts toward the use of SC in the classroom. The contradictions arise in the forms of use, in the levels of appropriation and in the values attributed to the products of scientific culture in each of these activities.

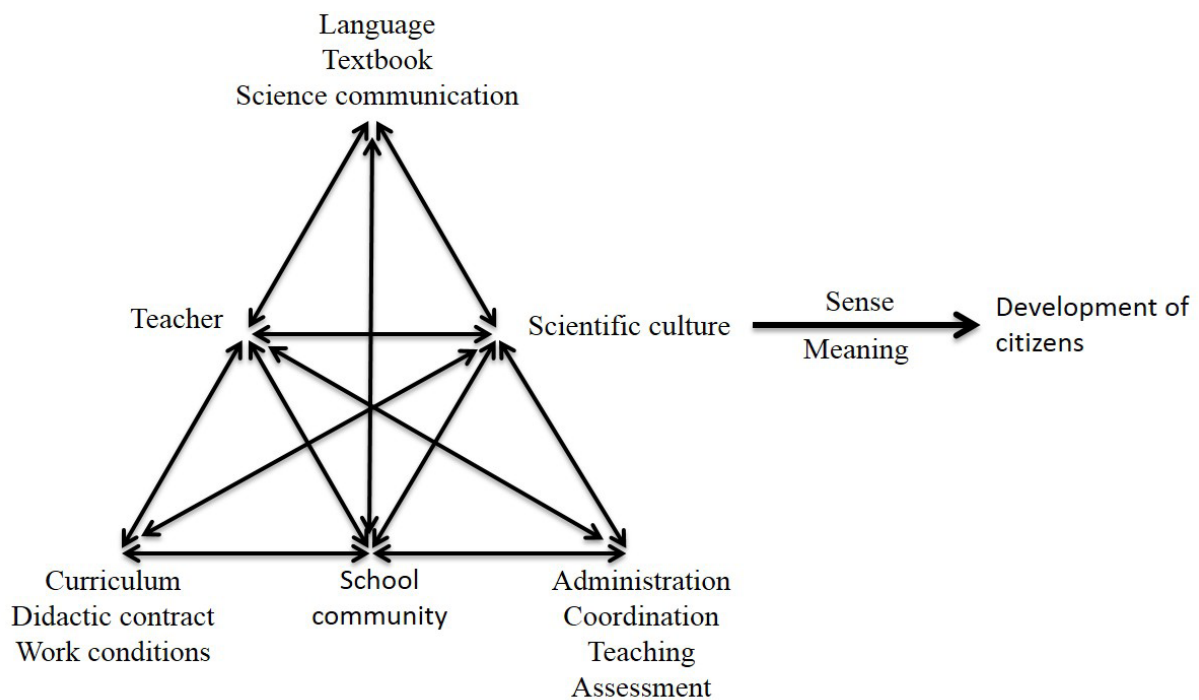


Figure 6. Scientific Education activity system

In addition, we must bear in mind that most SC resources are not intended for formal teaching situations and, in that sense, the teacher plays a relevant role in the relations between the SC Consumption (Figure 5) and Scientific Education activities (Figure 6). The teacher articulates the Consumption and Education activities, so that the SC can be an element of another activity system, demarcated by Teaching Planning (Figure 7). The teacher does that even if it is through a tacit knowledge and either in the form of a product or a material support. In that system (Scientific Education), which is closer to formal education, the object is a Didactic Sequence (DS), whose result or reason of production is science teaching. The Teaching Planning activity (Figure 7) is, therefore, a facet of the education's activity system, and we can understand it as a specific subsystem, related to the teacher's work; it was proposed and identified during the development of this research, being the result of an in-service teacher training program, in which teachers developed teaching plans to be applied in the classroom (Lima, 2016).

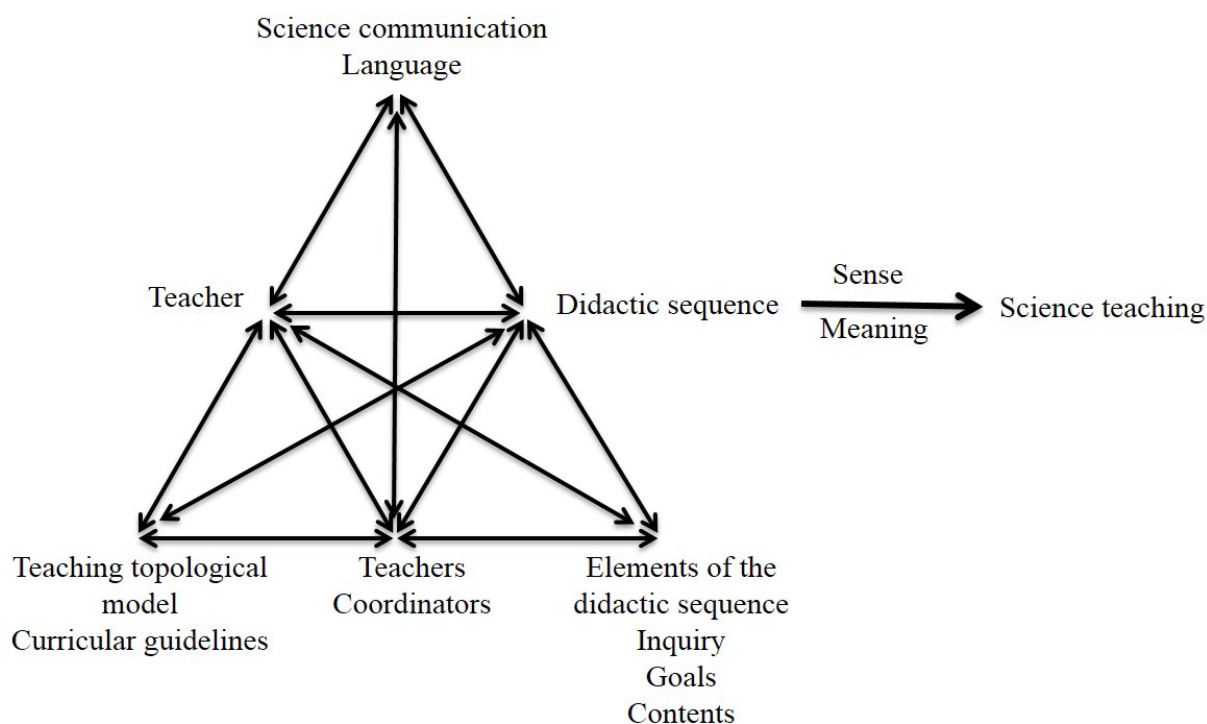


Figure 7. Teaching Planning activity system with SC resources

In the Teaching Planning activity (Figure 7), the teacher's object is the DS, being the SC the mediating instrument. Such activity was conducted by the community of teachers who have followed the rules established for the elaboration of the DS in the Science Teaching Specialization course – Redefor USP (EEC-Redefor-USP). The rules were based on the Teaching Topological Model (Giordan, 2008), which proposes a model to plan the Science teaching, having sociocultural contributions as its basis. The work was divided according to the DS production stages in the in-service teacher training course, which are: 1st stage – characterization of the target audience; 2nd stage – inquiry, general and specific goals of each class; 3rd stage – contents, dynamic of activities, assessment, bibliography and materials used (Nery, 2014).

It is through the DS that the teacher plans and organizes the actions that will be developed in the classroom. Therefore, the DS is something planned and is also the main element of the actions developed in the classroom. It guides the use of SC and reallocates the context of SC Consumption, which becomes a school activity for both students and teacher. In addition, the development of the DS with the SC resources is a relevant factor in the work of teachers that allows us to understand the appropriation of SC. This is indicated by its arbitrary use to attend specific purposes of the teaching activity. Thus, such appropriation draws the SC from its original places and purposes and inserts it into new socio-cultural contexts, that is, it is used as a cultural tool for teaching purposes (Lima, & Giordan, 2017a). In Figure 8, we present a fragment of a didactic sequence, produced by a teacher from the EEC-Redefor-USP course, to exemplify the

appropriation of SC.

Class	Specific goals	Contents	The dynamics of the activities
2	To develop autonomous attitudes toward the formulation of questions, presentation of doubts and interest in the theme.	The dimension of some stars in the universe. The shape, location and size of the Sun, Moon, Earth and other planets.	From the previous activity, it will be presented to the students two images (using a slide projector) of our Solar System (Figures - Available at: http://chc.cienciahoje.uol.com.br/plutao-um-planeta-anao/ and http://chc.cienciahoje.uol.com.br/um-sistema-solar-para-montar/); let them analyze the images for a few minutes and ask them some questions, such as: <ol style="list-style-type: none"> 1. Have you ever seen such an image? 2. What do you think that image represents? 3. That image is from the solar system. Does anyone know what the solar system is? 4. Where is the sun in that image? 5. Why is the Sun in the center? 6. Does anyone know what are these circles of varied sizes around the Sun? 7. Is our planet there? Which one it would be? 8. Our planet is part of the solar system. What is the name of the planet we live in? 9. How many planets appear in the picture? Do only these planets exist? <p>To survey the possible answers, a student should be invited to be the “scribe of the day”, writing down all the other students’ opinions on the board while they register them in their notebooks; they will also be encouraged to ask new questions that they would like to be answered during the study, fixing them on a support on the wall.</p>

Figure 8. Evidence of the use of SC in a fragment of the DS

Note. Retrieved from Lima, G. S. (2016). O professor e a divulgação científica: apropriação e uso em situações formais de ensino. Table 5, p 136.

The “dynamics of the activities” column in Figure 8 indicates that the teacher responsible for the DS plans to use two SC resources, indicated by the hyperlinks to the *Ciência Hoje* website. The use of infographics available at the *Ciência Hoje* website has the immediate purpose of surveying students’ conceptions, but the proposed lesson is geared toward achieving its specific objectives. In analyzing the contents to which the hyperlinks refer, we noted that the purposes delimited by the teacher differ from the ones in the articles from the website. According to Lima and Giordan (2017a), the purposes of the articles can be classified as explanation, metacognition and production of material. In the case of the fragment (Figure 8), the teacher adopted aspects of

the SC's discourse to compose the school scientific discourse. When adopting it, he established teaching purposes that meet his educational goals. Therefore, it occurred the autonomous use of SC resources, fact that characterizes its appropriation. The concepts the teacher approached were related to the content of astronomy, more specifically to the solar system. By understanding concepts as cultural tools, the activities of SC Production (Figure 4), SC Consumption (Figure 5), and Teaching Planning with SC resources (Figure 7) consider such concepts as mediating elements between subject and reality. In this case, the interaction between the activity systems occurs not only because they share objects, but also because they share mediational instruments.

It is important to mention the contribution of the activity theory to reflect on the processes in which scientific culture is the activity's object. It allows us to interpret the triggering of activities and/or interactions between them that are developed by subjects who share the same object. Undoubtedly, these activities are determined according to the conditions of SC Production and Consumption that, in turn, are responsible for the development of the subjects' cultural appropriation and production.

As we said, the DS organizes and delimits the actions developed in the classroom. Thus, it can trigger original activity systems and to assist the promotion of scientific education. That is the teaching mediated by SC in the classroom (Figure 9).

Teachers conduct teaching activities through DS, SC, language and the school scientific knowledge itself, which are the mediational instruments of such activities. The activity systems' object is the scientific culture. The division of labor includes the teaching activities of teachers, whose community consists of both students and teachers and they follow the rules established by the didactic contract. The main purpose of the Teaching system mediated by SC (Figure 9) is to develop citizens, as the official documents indicate. We recognize there may be other reasons, however they vary according to the particularities of the schools, teachers and students involved. We can again note the sharing of scientific culture as an object of the activity systems. We emphasize, however, that one of the main differences is related to the community in which the activity takes place, since it determines the forms of interaction and appropriation of scientific culture. The interactions and appropriations that are developed by the teacher, for example, establish stronger bonds than those produced by the students insofar as the teacher shares that object in other systems, which is represented in figures 5 and 6. As we have mentioned before, the SC is not produced for school. Thus, when the teacher uses its resources, he broadens the references to scientific culture, showing it can also be found in the social communication sphere. In such model, more than a representative of the scientific community, the teacher acts as a promoting agent of the scientific culture in the school, making possible the interactions with it that are beyond the borders of the school scientific knowledge.

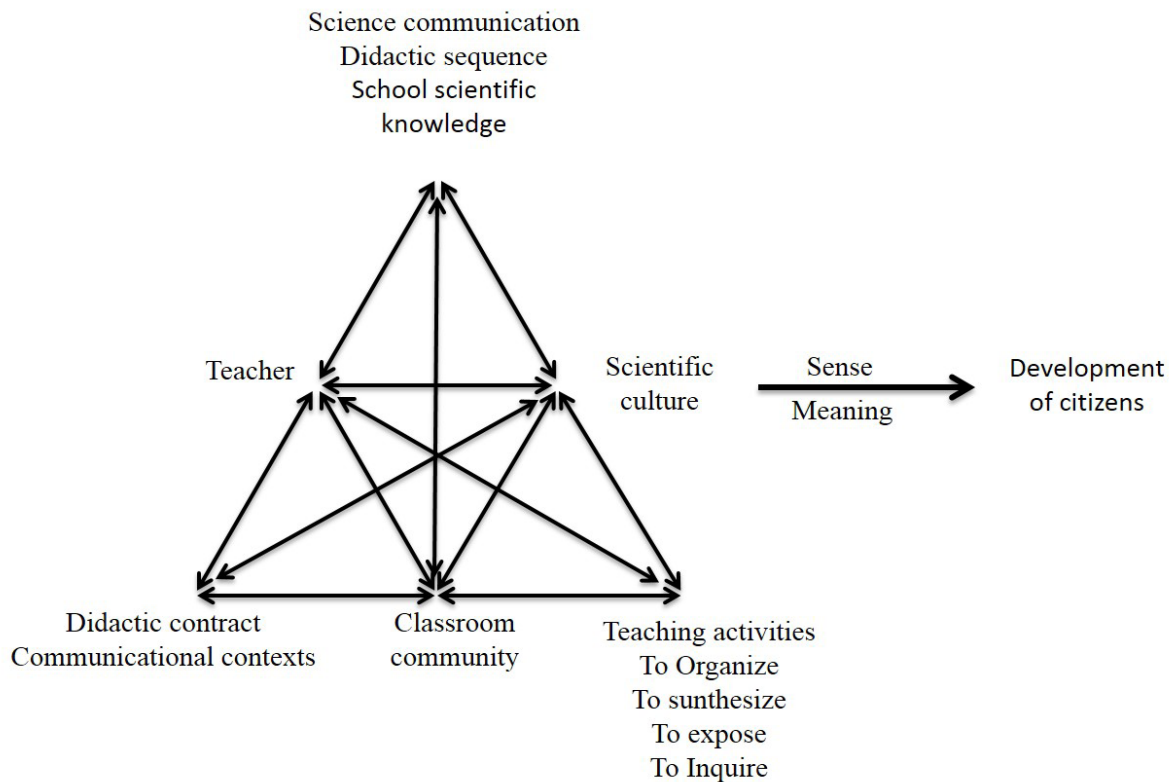


Figure 9. Teaching activity system mediated by SC in the classroom

Interrelations between activity systems in the promotion of scientific culture

The description of the main activity systems associated to the use of SC in teaching contexts provided us the understanding of the distinct positions that the SC has in the activities described. There are changes among the elements of the activities, indicating unfoldings that are promoted by the appropriation of their objects, with emphasis on the scientific culture. Such variations that were schematically represented showed us the SC as a cultural tool, therefore, a mediating instrument. From the SC Consumption activity, the subject responsible for the activities was the science teacher. He had the scientific culture as the main object of his activities, except in the Teaching Planning production (Figure 7), which is an auxiliary activity system to the insertion of scientific culture in school. Thus, SC and DS became cultural tools used to promote scientific culture through science teaching.

One of the variations that we consider as the most important is determined by the communities to which the subject who conduct the activity belongs. The teacher transited in several ideological creation spheres and, therefore, occupied different social roles in the activities that we described. The teacher integrated the scientific communication audience, the school community, the teachers and classroom community, which

conduct specific activities. Such fact occurs due to the division of the teaching work, which prompts the teacher to occupy distinct roles and positions when teaching.

The transit through the communities allows, in the last instance, the unfolding of interpersonal relations. These foment the insertion of subjects that do not take part in the communities in which the teacher participates. Given the focus of the research, this means that the teacher's movements gives students access to SC media that were not produced for that social group, which would probably not have access in other environments. Through the appropriation of it by the teacher, it is possible to expand the students' cultural horizon and insert them in new contexts, which leads to an expansion of the possibilities of interaction with and understanding of reality.

Such expansion is determined by tensions among the levels of appropriation of the scientific culture that the teacher and the student practice. When taking SC resources into the classroom, the teacher must adapt them to the levels of appropriation of students' scientific culture. That way, they can interact with a new resource, which until then may have not belonged to their social horizon.

The subject who performs the activity also deserves a special mention. The teacher is one of the subjects present in most of the proposed activity systems presented. However, in the SC Consumption activity, the subject's social role is not that of teacher. In Consumption, the subject's social role is of presumed audience and could be played by several other individuals. In the middle of consumption, the social role of the individual is transformed by the development of new activities and, in this case, we highlight the activities of formal education. The teacher performs several processes that allow him to appropriate SC and use it in activities that were not previously foreseen in his production. It is an expansion aimed at using this resource in situations other than those for which it was produced. To this extent, the nature of the transit between the activity systems allows the teacher to develop an expansive learning process, as proposed by Engeström (2015). Therefore, the level of appropriation of scientific culture by the teacher presents itself as an index of the transformations that SC provides in his/her development.

The transit through different communities, the different social roles played by the subjects and the variation of other elements of the activity systems allow us to note that activities are not isolated in their individual, social and cultural contexts. The activities permeate and trigger unfoldings caused by the appropriation of the objects and/or products generated.

The relationship between SC Consumption activities and Scientific Education is evident and mediated. In the SC Consumption activity, the subject and the motive are the consumer (teacher) and the cultural insertion, respectively; in Education, the subject and the motive are the teacher and the development of citizens. Despite the coincidence of the activity's subject, the teacher occupies different social positions, therefore, the actions he/she develops are not coincident. Such divergence provides contradictions that determine the form of use and the production of a new object. If on the one hand the teacher consumes DC for reasons such as curiosity and self-training, on the other

hand, the Scientific Education activity makes him/her responsible for the insertion of students into the scientific culture. Thus, during Consumption, the teacher is a consumer of products that promote his/her cultural interaction in the scientific community. On the other hand, in the Teaching activity (Figure 9), the teacher is the promoting agent of situations that lead to the cultural insertion of others: the students. The contradiction that emerges from between the position of a consumer of culture and a promoter of it is a reflex of the approach of SC in the school curriculum. Such relationship provokes new tensions as a result of the organization of the activity systems related to the school community. Therefore, it is very likely that the ways teachers work in these communities have important implications for students' insertion in the scientific culture.

The mediation of SC places another activity system in that interrelationship: the SC Production system. In the model we have presented, SC is a mediator in some activity systems. The interrelationship among these systems favors the multivocality, that is, the presence of voices coming from diverse positions and contexts of production. Thus, the use of SC in teaching situations occurs among tensions arising from at least three activity systems: 1) SC production (Figure 4), which delimits the audiences, themes and resources; 2) SC consumption (Figure 5), which provides the cultural insertion of the subject, and 3) Scientific Education (Figure 6), which aims to educate citizens.

Such interrelations promote the unfoldings of activities and discourses. Let us see: SC is the product of the Production activity systems, a condition that leads the teacher to consume it; the Consumption of SC, associated to Scientific Education, leads to the appropriation of SC to mediate teaching situations, which are manifested through didactic sequences in Teaching Planning; the Teaching Planning, in turn, guides the use of SC resources in teaching and learning contexts.

To better exemplify such unfoldings, we present in Figure 10 a diagram that synthesizes the interrelationships of the activity systems previously presented. We omitted the SC Production system (Figure 4) as well as the elements of the systems. Therefore, we present only the activity and products generated by the systems and/or the interaction between them.

The figure synthesizes the interactions between activity systems whose subject is the teacher⁷. Figure 10 was constructed to distinguish the levels between the activity systems, which indicate the hierarchy of the activities and the unfolding of causal relationships. The level 3 activity sphere is subordinate to the level 2 one, which in turn is subordinate to the level 1 activity sphere. This indicates that it is not possible to plan the use of SC resources in teaching situations without the articulation between the SC Consumption and the Scientific Education activities. It is even less possible to use SC in the classroom without its appropriation. Also, there is an indication of causal relationships that promote the unfolding of activities, which means Teaching Planning (level 2) is the product of a causal relationship between SC Consumption and Scientific Education (level 1).

⁷ Except for the SC learning activity system that was not described in this article. However, we consider it is relevant to signal the other possible unfoldings.

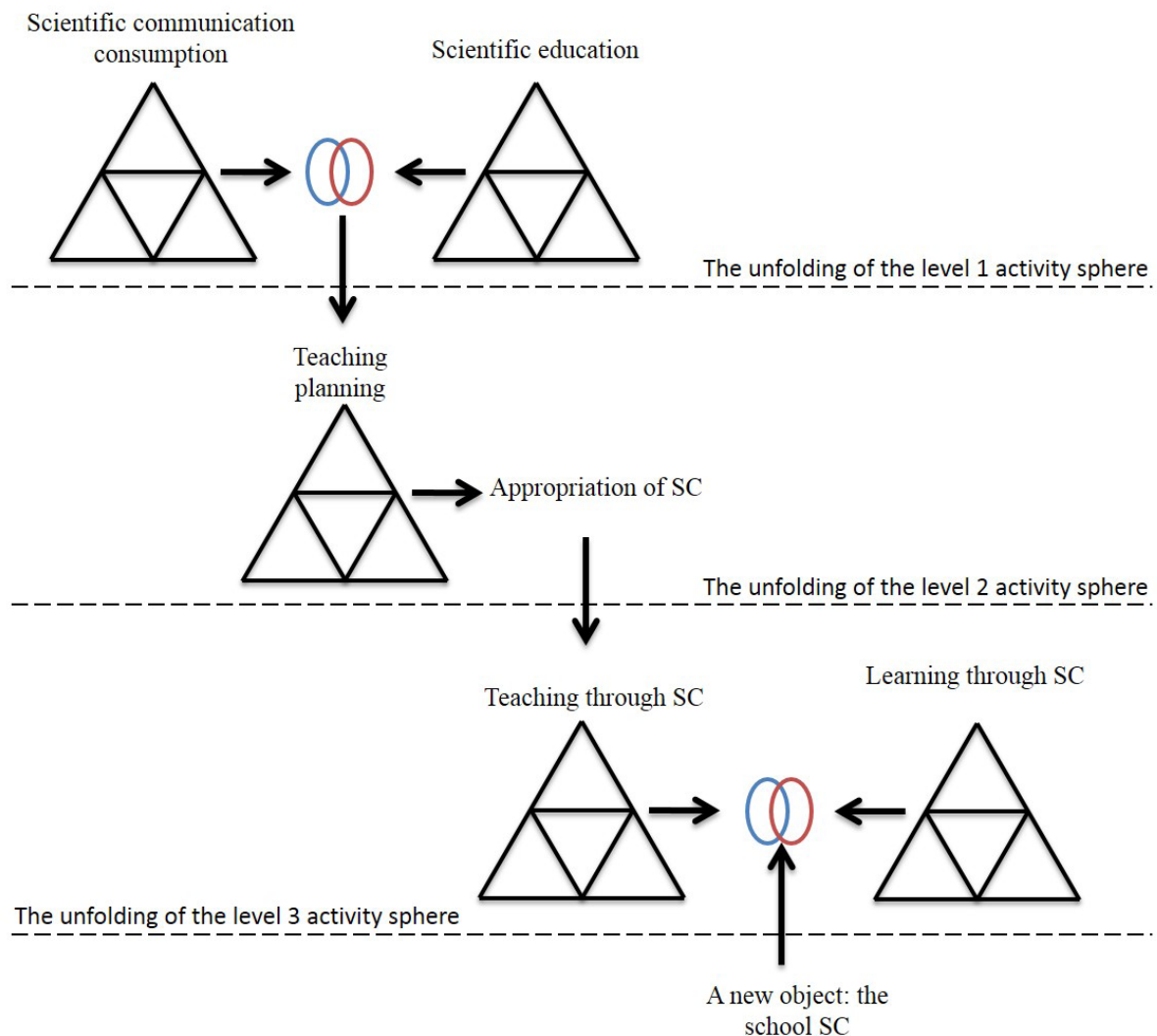


Figure 10. Interrelationships between activity systems that mobilize SC.

For example, the interaction of the Consumption activity systems with the Scientific Education promotes contradictions between *the objects approached by the SC* x *the objects that must be approached by the scientific education*. Such contradictions are evident if we highlight what motivates and determines the activities. SC Consumption is determined by its production and conditions of access, that is because SC is constrained by the publishing industry and its interests, as opposed to the Scientific Education which is mainly constrained by curricular guidelines. Thus, the objects are approached by different perspectives, which can cause the contradictions among the activities. Therefore, the object cannot be reduced to its materiality, that is, its function must also be considered in an activity system. If we consider identity as a unity opposed to contradiction, we will see that the identity of two objects is only achieved by juxtaposing the elements that determine them; their divergence can instigate contradiction, either because of infra-structural or super structural determinations. If we consider profit as

the main goal of the publishing industry and the citizens' development the main goal of education, the objects of these activities will have the germ of contradiction, whatever they are, even when they have an apparent similarity due to their materiality. It is through the synthesis of such contradiction that the teacher can understand the uses of SC in the classroom and in the teaching planning. When articulated with teaching planning, that synthesis promotes the appropriation of SC, which is evident due to the relocation of a cultural tool in function of the teacher's purposes.

Such synthesis often occurs through the comparison between the contents addressed by the SC and the curriculum. Rocha (2010) points that the "most relevant criterion for teachers when interviewed about the selection of Scientific communication texts is the relation between the subject approached in the article and those the teacher works with the students, that is, the articulation with curricular topics" (Rocha, 2010, p. 31). Although the sample investigated was small (5 teachers), the results presented indicate a synthesis of the contradictions between the Scientific Education activity system (Figure 6) and the SC consumption (Figure 5). We emphasize that is the teacher who does such synthesis and, in this case, occupies the position of subject in both activity systems. Deepening his investigations, Rocha (2012), indicated four elements that determine the choice of teachers, regarding the use of SC resources for didactic purposes, which are: their relationship with the curricular contents, their contents, their language and credibility. In our understanding, these elements can provoke contradictions when are present in different activity systems.

Rocha's studies (2010, 2012) indicate that during the selection of SC resources the Scientific Education activity is under the constraints of the SC consumption activity. Such constraints may even mobilize the teacher to adjust the chosen SC resource. Such adaptations have also been reported in other investigations in the Science Education, like those either made by the teacher (Martins, Nascimento, & Abreu, 2004) or to include SC resources in textbooks (Souza, & Rocha, 2017).

Almeida (2018) has contributed to the discussion about the tensions related to the use of SC in formal situations of teaching. According to the author:

A first aspect of this movement of tensions is that the teaching from the magazine, in the school context, is not a spontaneous process, on the contrary, it is controlled and guided by the established objectives and the school schedule. Another tension evidenced in the use of CHC [a Brazilian SC magazine for children] in the classroom occurs between the "closure" of the discourse that is intended in class and the "openness" that the article [from the CHC] provides, which is one of the sources of dialogism in the discursive movement (Almeida, 2018, p. 26).

Almeida's (2018) considerations indicate that the teacher conducts a process of synthesis to insert SC in the classroom, as

on the one hand, the presence of the magazine evokes practices already consolidated in the classroom, on the other hand, indicates tensions and conflicts that allow the emergence of new practices, other spaces of dialogue and possibilities of the teacher's

and children's saying in the relations they develop with the magazine (Almeida, 2018, p. 26).

Although not explored in detail, the Learning through SC activity system was inserted in Figure 10 to represent the disputes and contradictions regarding the use of SC in the classroom. These contradictions delimit the focuses and approaches on the teaching object, which are established between *what the students do not know yet* and *what they need to know in their education*.

The contradictions in the interrelated activities propel an original activity system, which we understand as an unfolding of the activity sphere, typical of complex activities.

To reflect on the unfoldings that occur between the activities and their products, we consider pertinent to remember some of the contributions that underlie the base of the activity theory. First, we use Leontiev's assertions about the complex activity, according to which:

Production demands more and more from each worker, a system of subordinate actions, and consequently a system of conscious ends that, on the other hand, enter in a single process, in a single complex action. Psychologically, the fusion of different partial actions into a single action constitutes their transformation into operations. Due to this fact, the content that once occupied, in the structure, the place of conscious ends of partial actions, occupies henceforth, in the structure of complex action, the place of the conditions to accomplish the action. This means that henceforth operations and conditions of action can also enter the realm of the conscious. On the other hand, they do not enter there in the same way as actions and their ends (Leontiev, 2004, p. 109–110).

The reflection on the functioning of complex processes can also be found in Marx's work. According to him:

An existing product in its form ready for consumption can become the raw material for another product, just as the grapes become the raw material for the wine. In other cases, work elaborates its product in such a way that it can only be reused as raw material (Marx, 2015, p. 260).

That characteristic of the complex work indicates the transformation of the product into raw material, which implies the transformation of the product into a means of producing another work.

When they function as a means of production in new work processes, the products lose their character of products. Now they simply function as objective factors of the living labor. (...) whereas in the well-elaborated product the it is omitted the fact that its useful properties come to us mediated by previous works (Marx, 2015, p. 260).

That process of transformation of products into means of production can be observed in the use of SC in teaching situations. Thus, if we develop an analysis from the Teaching activity with the use of SC, we will see that the activities in levels 1 and 2, in the figure 10, are mediating elements in the production of the Teaching activity that uses SC (level 3).

The transformation of the activity's products into elements that mediate other activities is evident if we compare the SC Production and Consumption activity systems. While SC is the product of the SC Production activity system, whose motive is the public communication of scientific culture, SC is the activity's mediating instrument, that is, SC is the cultural tool in the Consumption activity system. To paraphrase the interpretation of Marx and Leontiev, considering the Consumption activity system, the SC that was the product of the Production activity system becomes a mediating instrument of that activity, in conditions of the activity production.

The unfolding of activities that transforms products into instruments instigates multivocality, especially because most of these activities have the production of speeches as one of their products. Thus, such unfolding promotes the verbal interaction between subjects from activities that are not dependent on each other, as in the relationship between the SC Production and the Learning activity. These activities are essentially independent of each other. However, the interrelated model of activity systems that we have presented allowed us to understand that students interact with the SC producers through both SC resources and multiple mediations that occur in the teacher's movements. In the classroom, the activities related to the use of SC allow students to have access to the meanings the teacher produces when he acts as a consumer of a cultural good and as a teacher. Therefore, we suggest that the interrelationship between the activity systems represents a movement through which the teacher transits; he does that between different ideological creation spheres and promotes the enculturation of students in the scientific culture.

In short, we can note three origins of the enunciative production regarding the use of SC in formal situations of education, namely: production, consumption and education. We also pointed that even though the enunciative productions referring to the activities of Consumption and Education were elaborated by the same subject, they have distinct characteristics, since the subject's performance is developed for different purposes and with different social functions. We believe that to comprehend the unfolding of activities is the first step to understand the processes of appropriation and use of SC in teaching situations. Such unfolding promotes a discursive development, which means that the appropriation of SC by the teacher necessarily passes through the appropriation of the discourse of others. The teacher's discursive production, in turn, is composed by a discourse that is quoted. According to Bakhtin (2009, p. 149), "the discourse quoted retains its structural and semantic autonomy without, however, altering the linguistic plot of the context that has integrated it". In this case, the SC's discourse (the discourse quoted) is appropriated for the composition of the school scientific discourse (context that integrated the discourse quoted), that is, the SC's discourse supports the school discourse. This indicates the existence of a hierarchical structure among the discourses that are mobilized during the activities related to scientific education. It is worth emphasizing, however, that the activities and their unfoldings determine such interactions among the discourses.

The activities' hierarchical organization do not represent univocal interactions between levels. However, it implies that activities at higher levels are dialectically determined by activities at lower levels, that is, the activities we represented at the 3rd level are determined by the activities represented at the 1st and 2nd levels. Clearly, a direct constraint of a higher-level activity on a lower one is only possible in the reproduction of the activity, since lower level activities occur first. However, just as the science communicator can project the target audience in the SC Production activity, the teacher can project the unfoldings of SC, regarding its use in the Teaching Planning or in the classroom.

To comprehend the use of SC in teaching situations, as well as the teacher's movements to transform SC from a media product into a mediator in formal education, it is important to understand that the dialectical determinations are doubly oriented, through both 1) the temporal triggering of actions and activity products and 2) the teleological establishment of the possible and desirable unfoldings. We emphasize the importance of these determinations especially if the use of SC is based on an autonomous action of the subject, in which the teacher seeks to overcome the vices of the tacit, mechanical and alienated⁸ action of the educational activity.

Final considerations

In the current article, we have presented the teacher's movements toward the use of SC in formal teaching contexts. Our references were the activity theory, the proposals of systems and the interactions among activity systems based on Engeström (2001; 2015). In our analyzes we interpreted the teacher's interactions with SC in different activities: SC Consumption, Teaching Planning with SC resources, Teaching with the Use of SC. The DC Production and the Scientific Education activities were also analyzed, since they exert strong constraints on the SC Consumption and the Teaching Planning with SC resources.

The results we have found contribute to research and plan situations that make use of SC resources in formal teaching, as they trace the movement of the teacher toward that. From the model we have presented, it was possible to understand the unfolding of the use of SC in teaching contexts and to dialogue with other studies that investigate specific processes or stages of the use of SC in the classroom or its appropriation by the science teacher. We especially highlighted other research results that show the transformations, adequacies and disputes that occur with the use of SC in formal teaching situations (Martins, Nascimento, & Abreu, 2004; Silva & Almeida, 2005; Almeida, 2018). For example, the constraints of Scientific Education (Figure 6) that influence the SC Consumption (Figure 5) during the selection of its resources for formal education (Rocha, 2010, 2012). Moreover, we must mention that the use of SC in the

⁸ We consider the Marxist concept, which according to Bottomore (1988, p. 5) refers to the "action by which (or state in) an individual, a group, an institution or a society becomes (or remains) oblivious, strangers, ultimately, alienated to the results or products of their own activity".

classroom occurs due to actions guided by teaching purposes, which science teachers establish (Lima, & Giordan, 2017a); they, in turn, reflect the constraints of the Scientific Education activity system (Figure 6) on Teaching Planning (Figure 7).

We believe that the model of interrelationship of activity systems solves, at first, some difficulties to understand the use of SC in the classroom, since it is produced at the intersection of different ideological creation spheres. If we consider that SC is produced in the educational, journalistic and scientific spheres, as Grillo pointed (2013), we will understand that the principles of ideological creation spheres can be taken to the classroom in a greater or lesser degree, depending on how the teacher uses the SC. The foundations of such ideological creation spheres can deepen the contradictions among the activity systems and promote new forms of using SC in scientific education.

In addition, our model opens the way to understanding the teacher's movements for SC mediation in formal teaching situations. One of the highlights of such approach is the consolidation of a new practice of science teachers and their presence in different systems that have scientific culture as an object. Such multiplicity of roles can serve as a reference for students and teachers who wish to know or engage in issues involving scientific culture. The teacher can actively insert students in practices of scientific culture by combining them with alterity in the development of activities of scientific enculturation.

We also emphasized the transformations of activities' products into elements that mediate other activities. Such process occurs through the triggering of complex activities, instigating multivocality into them. Our hypothesis is that such transformations and multivocalities constitute an important research source to interpret and propose the conduction of science practices, from its initial communication process to the insertion of new members in the scientific culture.

These conclusions bear the need to recognize the teacher as a cultural agent of science, given his/her specialization, or simply a cultural agent. That is because we recognize him/her as a consumer and, at the same time, a producer of scientific culture; we also recognize his/her active role in the movement among distinct cultural spheres, therefore, in the transfer of cultural tools throughout the generations. In that sense, the mediation of teaching activities through SC is a privileged form of teachers' professional activity, considering it promotes the enculturation of students, insofar as the scientific culture remains the activities' central objects.

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Guilherme da Silva Lima

 <http://orcid.org/0000-0002-0049-5790>
Universidade Federal de Ouro Preto
Instituto de Ciências Exatas e Biológicas
Departamento de Física
Ouro Preto, Brazil
glima@ufop.edu.br

Marcelo Giordan

 <http://orcid.org/0000-0002-4646-0139>
Universidade de São Paulo
Faculdade de Educação
Departamento de Metodologia de Ensino e Educação Comparada
São Paulo, Brazil
giordan@usp.br

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