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How one science teacher redefines a science teaching practice around a theme: A case study in the context of educational reform in Québec

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In the context of an education reform in Québec, this case study illustrates how a science teacher's practice was redefined with nine classes over a period of four months on a specific, integrative theme inspired by issues of daily life in an attempt to increase her students' motivation and to better make sense of some scientific concepts prescribed in the new curriculum. Activity theory was used as a theoretical and methodological framework to analyze the development of the activity and revealed to be a fruitful approach to better understand real-life and complex situations within a school community. Special attention was given to dynamic relations and changes that took place as the activity was unfolding. The contribution of the nine classes in the analyzed activity was possible due to the collaboration of several members of the school community who shared the same goals and who sought to transform the learning environment.

Keywords: activity theory, curriculum studies, science teaching, teacher's practice

Introduction

This case study took place in the context of education reform in the province of Québec, Canada. In the Québec Education Program (QEP), high school science teachers were invited to implement a curriculum to encourage schools that were open to their respective communities to unite various participants (teachers, students, administrators, etc.) and to establish collaborations with numerous organizations and members within their community (experts, museums, parents, municipal government organizations, etc.) (Government of Québec, 2006).

Let us examine exactly how this new teaching approach differed from the Québec Ministry of Education's previous prescriptions and draws on new resources with which Québec science teachers were not necessarily familiar. The section of the Science and Technology component of the Québec Education Program (QÉP) going under the heading of "Pedagogical Context" sets out a number of avenues for classroom practice that encourage teachers to move away from a strictly disciplinary approach to science teaching (Government of Québec, 2006). We are referring specifically to a kind of science teaching that is no longer centred on scientific phenomena as such (e.g., falling bodies) but that is instead rooted in themes that foster the appropriation of scientific concepts (Barma, 2007; Government of Québec, 2006). It is also worth noting that experimental science teachers would prefer to avoid discussing complex, controversial issues owing to a lack

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of expertise or time (Urgelli, 2008). Indeed, the implementation of such educational programs means securing the adherence of several members of a school community as well as investing considerable time in developing new classroom practices – two major, potential stumbling blocks (Brant-Pomares, Aravecchia, Bally, Buisson-Fenet, Conio, & François, 2008). Hartley (2009) has argued that it is hard for teachers to change their routine, all the more so since organizational structures and pedagogical processes have proved remarkably resistant to change. That being said, and although science teachers generally opt for a discipline-based practice in a knowledge transfer process (Tobin, Tippins, & Gallard 1994), an increasingly worthwhile avenue would appear to consist in offering students more fully embodied activities concerning the world in which they live and act (Osborne, 2003).

In this context, the province proposed that its Grade 9 science teachers develop and implement socially meaningful learning and evaluation situations (LES) based on the theme *The Human Organism.* In so doing, and by presenting a complex problem to their students, teachers could propose a variety of tasks reflecting different learning styles (Government of Québec, 2006). This required of teachers that they demonstrate creativity in the approach they would now take toward science teaching and that they make adjustments according to the interests of students. An LES framed according to a given theme should thus feature three main characteristics:

> *A learning and evaluation situation is contextualized when it focuses on current events, scientific and technological achievements related to the students' everyday lives… A situation is open-ended when it is based on information that can lead to different possible solutions. The initial situation can involve complete, implicit or superfluous information. In cases where there is not enough information to solve the problem, students will have to do additional research, which will contribute to their learning… An integrated situation is based on concepts from different areas of the program* (Government of Québec, 2006, ch.6, p. 9).

One of the greatest challenges for any practicing teacher dealing with the reform is the fact that the new program aims at integrating traditional scientific disciplines (biology, geology, astronomy, chemistry, physics, technology) into a new program called *Science and Technology*. Since 2006, high school science teachers have had to find ways to leave their traditional monodisciplinary teaching approach in order to integrate concepts emerging from four "Universes" (Living World, Earth and Space, Technological World and Material World).

> *The program is organized in this way to make it easier for teachers to identify the key concepts that students should learn. However, since these areas are but interrelated, they should not be addressed separately or sequentially. The same applies to the concepts, which should not be covered in a predetermined chronological order, but through integrated learning and evaluation situations* (Government of Québec, 2006, p. 22).

In order to better grasp the practical implications for Grade 9 Science and Technology teachers, the main theme that had to be developed over the course of the year was "The Human Organism." Teachers had to contemplate discussing this issue in relation to the external physical factors that can have an impact on the human body's various systems (circulatory, respiratory, nervous, etc.). What is more, teaching approaches had to be varied, drawing on, for example: use of inductive analytical strategies, development of experimental protocols by students; development of conceptual networks, and lecture-style courses, occurring only once students had performed an information search. Thus students were prompted to play a more active role in their learning process and teachers were encouraged to be less directive.

Our research also considered several studies in science education focusing on the goals pursued by science teachers through their teaching practices (Beane, 1997; Fourez, Maingain, & Dufour, 2002; Hodson, 1999; Lemke, 2001; Roth & Lee, 2004; Roth, 2006). According to these authors, an authentic "integrated curriculum" must offer a certain features, including activities and issues pertaining to personal and social aspects of daily life, and cooperative student/teacher construction of the curriculum. We examined how many of these studies provide leads to innovating science teaching practices by taking into account the goals, epistemological postures, and teaching contexts that may result in a more democratic and socioculturally based atmosphere in science education. For example, in a socioconstructivist posture, Fourez, Maingain, and Dufour (2002) proposed that teachers engage their students in socially meaningful activities anchored in daily experience. In this manner, the scientific knowledge being constructed is mobilized for immediate use.

Many aspects of these suggestions, such as involving students in the choice of issues that are of interest to them (Beane, 1997), taking education beyond schooling (Roth, 2006), learning activities that take place on many context levels (Lemke, 2001), constructing representations around actual issues and real-life notions (Fourez, Maingain & Dufour, 2002), are coherent with the development of scientific literacy in the spirit of democratization in science education.

In more general terms, Sannino and Nocon (2008) described that when curricular reforms were implemented, motivated teachers adopted new ways of teaching in the classroom. Barma (2011b) has documented that in science, teachers initiated new didactical practices to test their academic training or to increase their students' motivation. Furthermore, in adopting activity theory, a number of recent studies documented how the efforts by schools to bring about pedagogical innovation have either managed to be translated into action or have failed to be implemented altogether (Engeström, 2008; Nocon, 2008; Yamazuni, 2008).

In this case study and in the context of the proposed reform, we focused on how a Grade 9 biology teacher who questioned her teaching practice made it possible to engage in modeling an LES with an integrative theme and attempted to more efficiently contextualize a fair number of prescribed concepts (Government of Québec, 2006). We also sought to further investigate the ways in which her classroom practices were shaped as she was motivated to change her teaching practice in accordance with the new prescriptions in education, such as the development of three disciplinary competencies.

> *The first competency focuses on the methodology used to solve scientific and technological problems. The students become familiar with concepts and strategies in a hands-on approach [...]. The second competency focuses on the students' ability to conceptualize and apply what they have learned in science and in technology, especially when dealing with everyday issues [...] The third competency involves the different types of languages used in science and technology, which are essential for sharing information as well as interpreting and producing scientific or technological messages* (Government of Québec, 2006, p. 3-4).

As our research unfolded, we also examined how, over a four-month period, some school community members, who shared this teacher's motivations, facilitated the construction of knowledge and meaning in a school environment that subscribed to the principles underlying a reform of science education curricula.

As we undertook this research project, several questions emerged. In this article, we chose to address the following ones: 1) How does a high school science teacher engage in modeling and implementing a LES around a theme pertaining to *The Human Organism* in order to move away from a lecture based class? 2) All along the development of the activity, what were the scientific concepts mobilized by that teacher?

The results of this case study concur with a general trend in research relative to new practices in science education (Méheut, 2006). Situated in a Québec context (Government of Québec, 2006), our findings provide an illustration of how, over a four-month period, a Secondary III (Grade 9) biology teacher, in an attempt to better understand and appropriate the QEP, reexamined her teaching practice by modeling and experimenting with nine science classes which she qualified as being innovative because it was different from what she had done previously – i.e., a lecture-type teaching approach coupled with highly directive lab experiments. The overall theme of the nine activities, which involved four groups of approximately 30 students aged 14 to 15 years, was the development of awareness among teenagers as to the risks of tanning salons on their health.

Theoretical Framework

Following the conclusions of a group interview conducted by one of the authors with seven Québec high school science teachers, the third generation of activity theory (Bracewell et al., 2007; Engeström, 2001) was selected as the theoretical framework to interpret the renewal of classroom practices in science classes (Barma, 2008a). This framework emphasizes the contextual and systemic aspects of practices recognized as being innovative. According to Bracewell, Sicilia, Park, and Tung (2007), Engeström, (1997), and Miettinen (2006), theoretical frameworks based on a sociocultural theory of learning can enrich how we consider a unit of analysis and thus enable us to interpret data in a systemic and contextual way.

Activity theory examines human activity in terms of being socially situated – for example, in relation to the world of labour or that of learning (Parks, 2000). The origins of this theory are found in the work of Vygotsky (1978), who considered the development of human behaviour to be above all mediated by the creation and use of material or symbolic cultural artifacts (e.g., instruments, signs, symbols).

When adopting these premises, action and the context in which the activity takes place are not considered separate from one another (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991). Thus the activities undertaken by an individual are closely related to a conscious goal, a motivation that is linked to the actual context in which the activity is occurring. According to Vygotsky (1985), a human being is defined with respect to his or her activity with objects (not solely material) and actors in his/her environment.

Leont'ev (1978) developed the second generation of this theory. This author emphasized the distinction between individual and collective action and considered the complex interactions occurring between an individual and his or her community. In his view, labour is essentially cooperative. In human societies, the meaning attributed to a given activity is thus shared by a community of actors who pursue the same goals. For this reason, mediation is characterized by the division of labour and the rules that frame the interactions between individuals belonging to the same activity system and pursuing the same object. Leont'ev argued that it was important to distinguish the concepts of activity from those of the actions related to the implementation of this activity. "An activity is associated with a purpose, an action with a goal, and an operation with the conditions necessary to its execution" (Class, 2001, p. 2; authors' translation).

In the 1970s, Western researchers began recontextualizing activity theory, to a much greater extent than in the period following the death of Vygotsky, the founder of this theory

(Vygotsky, 1985). In line with a study by Latour (1993) on the human/non-human actor network, the concept of activity networks was thus developed. Engeström (1999) later created a systemic model based on the first two generations of activity theory by integrating the socioinstitutional infrastructure of the activity, namely, rules, the division of labour, and elements of the community. For Engeström, it was increasingly crucial that we recognize that an individual's interactions with the world are mediated by objects, methods, rules, and values as well as all other aspects of human culture. Hence, the author positioned the individual at the centre of an activity system consisting of six interrelated poles (subject, tools, rules, division of labour, community, and object of study), with each pole representing different key nodes of that system (see Figure 1). Although these poles may presumably be considered separately, they must be interpreted as being interconnected. From a methodological standpoint, Engeström (1999) argued that his model provided a dynamic reading grid for the analysis of the transformation of social practices.

The concept of activity itself must first be defined. Activity is therefore a goal-oriented and tool-mediated action; the activity pursued by the subject is analyzed in its dynamics and transformations as well as in its evolution and historical change. "This theory regards innovation as a process of shared construction of an object, a mobilization of essential and complementary cultural resources as well as a process of mutual learning" (Miettinen, 2006, p. 176).

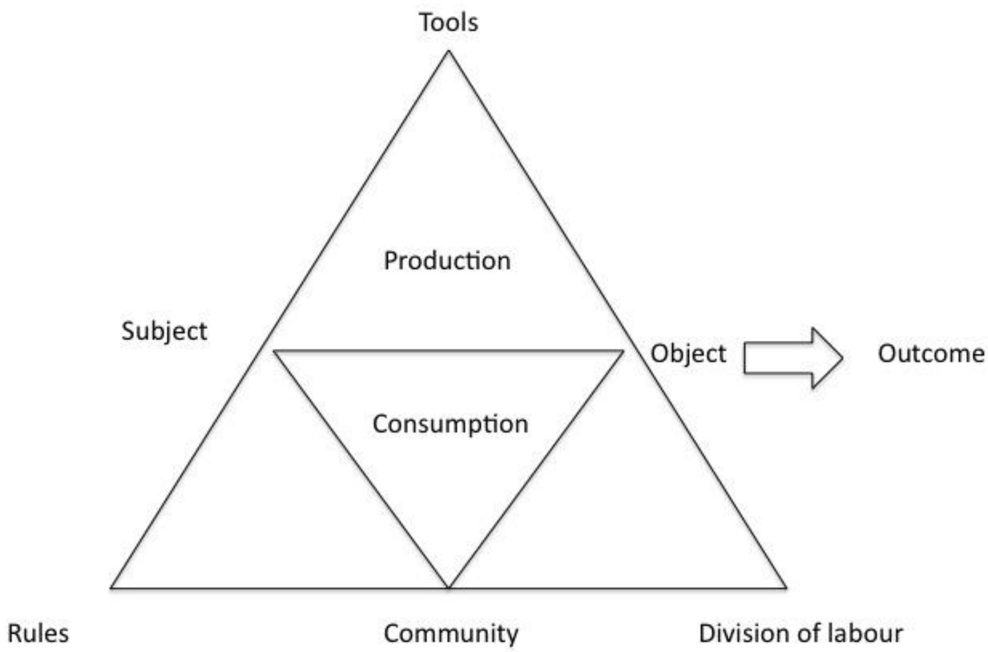

Figure 1. Activity system triangle (Engeström, 1999).

Based on the elements of activity theory, each pole of Engeström's triangle may thus be defined:

1. Subject: the acting person or persons (individual or group of individuals involved in the production, exchange, distribution, and consumption of the activity).
2. Object: the outcome (e.g., an LES around a specific theme).
3. Tools: symbolic and material artifacts that mediate the activity.
4. Community: a group of collaborating individuals who share the same object.
5. Division of labour: the horizontal redistribution of actions among subjects or community members and the simultaneous vertical hierarchy of power and status.
6. Rules: standards, conventions, implicit/explicit habitual means of maintaining and regulating actions and interactions within a system.

The ability of subjects to mobilize other actors of the system and to unite them around the same object is a generational prerequisite of an innovation within an organization or local community. "These [learning-centred] relationships are not based on written contracts but rather on the norm of reciprocity, based on the complementarity of the knowledge, resources, and interests of the actors" (Miettinen, 2006, p. 176).

At this point, it is important to talk about some limitations of the triangular representation of activity. As Sannino (2011, p. 577) points out, "one red thread identifiable through the critiques of the triangular representation of the activity system and related contemporary developments in activity theory is the claim that these works neglect key ideas of the founders." For example, the issue of subjectivity and personal sense explaining the intentionality of an individual as he or she engages in a certain action more than another is sometimes difficult to illustrate when focusing only on an activity system (Lee, 2011; Roth, 2009).

As researchers, we find that one of the challenges of working with activity theory is to make sure that the way we present our results does not become reductionist. This paper does not focus specifically on the intentions, the emotions and the conflicts that the science teacher expressed as she was engaging in modeling a new LES. Barma's (2011b, 2011a) research papers documented how this particular science teacher's life experiences and emotions led her to resolve many tensions in order to overcome a certain degree of paralysis. She had been experiencing such paralysis for some time and she wanted to modify her teaching approaches. Dialectical thinking allowed her to envisage construction of new solutions.

In this contribution, we used activity theory as we analyzed the development of nine science classes that constituted the essence of the LES modeled by a science teacher with a special attention given to dynamic relations and changes over the four month period. So, in that sense we espoused Engeström's position when he states that the triangle "is not a representation of the system as it is; it is a representation of the central elements and relations of a system to be built and implemented in time" (Engeström, 1985, p. 20). As Yamagata-Lynch (2007) has brought out, it helps us researchers to better understand real-life and complex situations.

Methodological Framework

As pointed out, activity theory was selected for this study, as both context and mediation were considered while examining the production of a new LES centered on a theme: *Awareness of the Risks of Tanning Salons*. We were thus able to look at a teacher's practice through a systemic approach that took into account the contribution of tools in mediating the production of a new LES and the role of the actors who shared common goals within their educational community (Engeström, 2001). An ethnomethodologically inspired approach (Denzin & Lincoln, 2005) consistent with activity theory (Engeström, 2001) was also very helpful in this research. Accordingly, the investigative format selected for this research was the case study, which lends itself well to scrutinizing and grasping objects of study (Stake, 1995). Indeed, Murphy and Rodriguez-Manzanares (2008) observed that case studies were usually chosen for the study of activity systems.

The case

The case described in this study involves a high school biology teacher with five years of experience who was responsible for four groups of Grade 9 and one group of Grade 11 students.[i] Barma (2011a) detailed the experiential trajectory of the participant's practice through some of her autobiographical narratives and focused on the cultural/historical dimensions of the shift in her practice over the four-month period. This contribution focused on the relevance of centering a teaching activity on a theme so as to better appropriate the prescriptions of the new science curriculum (concepts, open-ended teaching approaches) and move away from a lecture-based teaching style. The most important elements that characterized the participant's motivation are summarized, followed by an overview of the nine classes put together by this teacher as she sought to change her way of intervening in the classroom.

A Summary of The participant's Motivation

Having worked in the same school for five years, the participating teacher had a Bachelor's degree in secondary education with majors in biology and mathematics. When preparing her lesson plans, the young teacher claimed to have spent over two hours per week on designing activities other than the ones suggested in the school manuals. Although she had taken many courses in pedagogy (renewal of pedagogical approaches, ICT integration in the classroom) at the beginning of her career, she considered her level of expertise in the program to be rather low. Our investigation revealed that despite her willingness to participate in a research project, she expressed having a high level of anxiety at the thought of having to plan and introduce novel teaching/learning activities, as she had not only failed to grasp the principal guidelines of the proposed reform in science and technology, but had also always taught only one subject at a time (biology or mathematics) and therefore had no idea as to how they could be combined around a common theme. Furthermore, although she questioned certain aspects of her university training, she wondered how her lecture-based classroom interventions could be adapted to comply with the new reform. The issue of evaluating concepts also concerned her and made her question its feasibility, should she engage in a different way of presenting scientific concepts to the students. In the lab sessions, the experimental protocols were always given to the students, thus leaving them with little flexibility in terms of manipulation.

Prior to participating in the study, the teacher identified several causes of tension that she felt had to be addressed: the lack of sufficient training for teachers to enable them to master the reform; time constraints; the lack of information as to how lecture-based courses could be reduced; how to deal with colleagues who felt humiliated or disconcerted with regard to the proposed reform; the lack of flexibility of the time schedule in terms of eventually implementing activities in educational communities. Barma (2011b) documents how she overcame these dialectical tensions in order to engage in a construction of new meanings in her school.

As she began to collaborate with us, and in light of her realizing that many of her students expressed feeling proud to use tanning salons, she decided to launch an awareness program (with the support of the school principal) and get her students involved in addressing this issue. Thus over a four-month period, she designed (what she qualified as) an innovative course planning to redirect her teaching toward the theme of the risks of tanning salons. To her, an issue taken from the daily experience of many of her students not only had merit but would also comply with the ministerial prescriptions calling for science teachers to anchor their practice around the theme *The Human Organism.* During the period when the study was being conducted, the controversy surrounding the risks of tanning salons was the subject of considerable coverage in Québec's French-speaking media, with several outlets striving to arouse public awareness of this issue. Thus, the teacher saw an opportunity to make good on ministerial prescriptions according to which a current social issue should serve as the rationale for implementing an LES. In doing so, she believed that she would better understand how her students could develop the newly prescribed competencies.

The primary concern of the participating teacher was 1) to develop her students' autonomy by getting them to learn concepts by themselves and 2) to establish links between these various concepts. She focused specifically on Competency no. 2 which "requires that students put an issue in context, identify the related scientific and technological principles, and form an opinion" (Government of Québec, 2006, p. 15). She also wanted to distance herself from the lecture-based approach she had been used to as a student and had later espoused as a science teacher.

The nine Science Classes that Constituted the Analyzed Activity

Over a four-month period, she planned and implemented an open-ended LES around the theme *Awareness of the Risks of Tanning Salons* (nine 75-minute classes). As a science teacher, her strong motivation was to vary her teaching approach when carrying out the awareness campaign in her school. She felt that it was important that she empower the students to make better choices in regards to their health. For this purpose, while she had to ensure that the scientific concepts targeted by the activity (the 9 classes or the LES) were appropriated, she also wanted the students themselves to identify these concepts. Table 1 presents a summary of the nine classes focusing on the theme chosen by the teacher. Each class lasted 75 minutes.

Data Collection and Analysis

Data was gathered on a regular basis over a four-month period in a Québec high school where the LES was implemented. In 2008, this school had a teaching staff of close to 40 teachers and roughly 650 students aged 12 to 17 years. Semi-structured and informal interviews were conducted with the participating science teacher directly in the school. The documents pertaining to the lesson plan preparations were also analyzed. The implementation of the LES was discussed with the teaching unit director on two occasions and with the laboratory technician on three occasions. For the purpose of assessing the impact of the implemented practice on other teachers, discussions were held on four occasions in the teachers' room and also with the participant's teaching colleagues (in the Science, French, and Technology Departments). While it may have been of interest to pursue the interviews over a longer period of time, the teacher's schedule coupled with the pressure of a summative evaluation during that period warranted that the interviews be limited to a single semester. The students, on their part, were not interviewed during the planned activity implemented by the teacher; however, the information on their summative evaluation was made available and was considered in the present case study. The reason why we present the questions appearing in the teacher's summative evaluation is that they give evidence of a practice that is more open-ended, integrated and contextualized and that thus accords more fully with the characteristics specific to a LES, as described at the beginning of this article.

During the data collection period, our analysis alternated with fieldwork in accordance with the principles of grounded theory (Charmaz, 2005) in the assessment of each pole of an activity system and their interrelations. Throughout this phase, refinements made to the model (transitional activity systems[ii]) were validated by means of an ongoing comparison of the observations and the emerging analysis. Triangulation was performed in relation to the observations retained during our meetings with the principal, the technician, and the other teachers. It should be noted that these meetings occurred on an informal basis, considering that we had adopted an ethnomethodologically inspired approach. Specifically, this worked out to more than three meetings with the principal, five with the laboratory technician, and several meetings with the other teachers when we happened to be in the teachers' room and we launched into discussion about the project. Identifying activity systems came into sharper focus through a characterization and correlation of categories (subject, object, rules, division of labour, community, tools), a charting of how these categories interconnected with one another, and a modeling of the dynamics of the many activity systems stemming from our analysis.

Table 1. Summary of the Nine Classes on the Theme of Tanning Salons

Class 1	Lunchtime discussion (all of the students) with a dermatologist on the risks of UV exposure on human health. To interest the students, an expert is invited to give a talk and answer their questions. The class takes place at lunchtime and is presented simultaneously to four groups of students. Other teachers are present.
Class 2	Discovering activity on skin functions. Inductive approach in a laboratory setting. The students are invited to develop their protocol based on materials provided by the teacher. The class concludes with a plenary session during which the teacher summarizes the teams' results. The focus is Competency no. 1.
Class 3	Information search by the students. Team production of concept maps. Informational documentation is given to each team who must identify the main principles and concepts targeted by the issue of UV exposure and its associated health risks. The teacher compiles their findings at the end of the class. Development of Competency no. 2.
Class 4	Lecture-style course given by the teacher on the electromagnetic spectrum.
Class 5	Inventory of ingredients in sunscreen provided by a pharmacy. This class focuses on developing Competency no. 2: Analyzing a technological product to enable the appropriation of scientific concepts.
Class 6	Forming of teams and launching of an awareness campaign for the entire school community. Each team decides what it deems is pertinent information in regards to tanning salons. Co-construction of meanings by the students. Focus on Competency no. 2 and no. 3.
Class 7	Continuation of teamwork.
Class 8	Display of posters in a public area in the school. Competency no. 3.
Class 9	Production of a moisturizing lotion in the laboratory. Technological design of the product. During this class, the development of Competency no. 1 is targeted and focuses on the appropriation of concepts and strategies using a hands-on approach. Reinvestment of Class 4.

It should be pointed out here that initially, six participants from four different secondary schools volunteered to participate in this research project. Of the six participants, only one effectively planned and implemented new activities in her science classes, whereas the other five did not pursue their initial intention, either because of work commitments, a lack of understanding of the reform, a lack of support from their superiors, or a lack of flexibility in their time schedule for evaluation purposes (Barma, 2008b). These observations are in agreement with the findings of a case study undertaken by Nocon (2008) who investigated why desired changes failed to take place in a school and highlighted such reasons as the pressure to conform to curriculum objectives, the teachers' inability to personalize their didactical practice, and an overload of tasks, to name a few.

The meetings occurred between January and May 2007. Although the participating teacher had a heavy workload and found it difficult to adjust her schedule for the meetings, five semi-structured audio interviews were conducted and recorded over a period of four months. In order to respect the participant's work pace, it was decided that she would select the time and date of the meetings where we would share with her the various steps that were to be followed to innovate her practice. Each semi-structured interview was conducted at her school. The corresponding verbatim, which was transcribed integrally, constituted our primary data. To ensure an accurate interpretation of the verbatim, open e-mail communication was established with the participant, thereby enabling a clearer interpretation of how she planned and implemented an innovative LES for validation. The participant's lesson planning documents were also analyzed, along with the exam she prepared in line with her LES for the four classes of students.

The first semi-structured interview focused on certain aspects of the participant's cultural/historical identity as well as her understanding of the new science and technology program (see Table 2). Her conception of innovation in science teaching was also examined. The second, third, and fourth interviews were entirely dedicated to the description of her lesson planning and the implementation of the LES in class with her students. There was no specifically designed formal interview protocol for these interviews; the participant led the discussions and answered questions for clarification purposes. The meetings for the interviews were separated by nine and thirteen days, respectively; the second meeting took place six weeks subsequent to the first one. The fifth and last interview was held three weeks later. During this time, the teacher continued planning and implementing her new LES, while we explored the conditions that could either facilitate or interfere with her goals. She described how things progressed and was then asked to compare the new LES and the one previously used with the students. The participant also explained why she thought she had been able to innovate and still make sure that the students acquired scientific concepts.

Analytical Approach

Our analysis was performed in compliance with the poles of an activity system and other analytical methods related to this model (Bracewell et al., 2007; Engeström, 2001; Sawchuck, Duarte, & Elhammoumi, 2006). We proposed four levels of analysis to render the methodological orientations of Engeström's triangle operational. This constitutes an original approach in the interpretation of teachers' activity as they attempt to transform their practices (Barma, 2008).

The first level of the open-ended content analysis (L'Écuyer, 1990) characterizes each pole: subject (science teacher), object (the new LES), tools (artifacts that mediate the activity of producing the LES), community (actors sharing the activity of production), division of labour between the different community actors involved in the planning and the implementation of the LES, and rules (implicit and explicit rules set within the school community). The open-ended coding was done with NVivo and it allowed us to define each pole of the unit of analysis that constitutes an activity system.

In order to provide a more systemic and contextual reading of the data, we then focused on individual sub-triangles (see Figure 2) within an activity system. Each one highlights the interrelations between the three poles of a sub-triangle within an activity system and can greatly contribute to the understanding of the entire activity system. If we go back to the second generation of activity theory and the emergence of mediators in a collective activity, it seems relevant to analyze several triangles within the activity system.

Table 2. Interview Protocol

First semi-structured interview protocol: Investigation of the cultural/historical aspects of the participant and first inquiry on the new science and technology curriculum
1. What is your academic background?
2. Do you think that it has any impact on the way you teach now?
3. What kind of students do you intend to train (develop) as you are planning learning and evaluation situations in the context of high school science teaching? What is your vision of a good science teacher?
4. In a few words, how do you define yourself as a teacher?
5. What motivated you to become a high school science teacher?
6. What makes you persevere in this profession?
7. If you compare your current teaching abilities with those when you began teaching science, do you see your teaching as something continuous or changing?
8. In your opinion, compared to the "old" programs you have previously taught, what appears "new" to you?
9. What is your understanding of Competency no. 2: Making the most of his/her knowledge of science and technology?
10. In your opinion, what does "taking into account multiple aspects of an issue" mean in the context of science teaching?
11. In the current context of your teaching, when you prepare an LES for your students, what type of resources do you seek?
12. In the context of the educational reform in Québec, we often hear about innovation. What does innovation in science teaching mean to you?
Second semi-structured interview (looking back on the first steps of the new LES)
1. Do you consider that the learning and evaluation situation that you have planned thus far is innovative? If so, in what way? If not, why?
2. What resources did you seek? Were they available to you?
3. In your opinion, in the context of science teaching, what conditions are required for innovation?
4. In your opinion, what could your school do to support you in your efforts to innovate in the context of the current pedagogical reform?
5. Are you able to identify any sources of tension?
6. Are you able to identify any sources of stress within your school community that would affect your ability to innovate while planning or implementing an innovative LES?

In *Learning by expanding*, Engeström (1987, p. 80) brings out the fact that: "The sub-triangles are initially only actions since their object is still a relatively undifferentiated whole… and the temporal, spatial and social boundaries between them are fluid… However, demanding tasks… very early acquire a division of labor of their own and become relatively independent activities. He also emphasizes the importance of the sub-triangle production. "Among consumption, production, distribution, and exchange, production plays a particularly important role" (Sannino, 2011, p.575). There is no activity without the production of a new object.

In the context of the present study, the analysis of these sub-triangles illustrates how the new LES was produced, exchanged, consumed and distributed within the school community.

Figure 2 (exchange or communication) presents an example of how current-teaching practices can either facilitate or interfere with a teacher's willingness to innovate their approach. This raises important questions: How do parents react to such innovations? When introducing new curriculum, can a science teacher change some of the implicit and explicit rules within the school community? Are these rules renegotiated, and if so, how? Engeström (2001) identified this sub-triangle as an "exchange" that is crucial to better understanding the interactions between the subject and the other members of the community who share the same object and goal, and also how implicit or explicit rules are redefined. In the results section, we also chose to present a second sub-triangle (Figure 5) – "consumption" – to illustrate how many members of the school community shared a common goal of making it possible for the teacher to vary her teaching methods and move away from a lecture-based teaching approach.

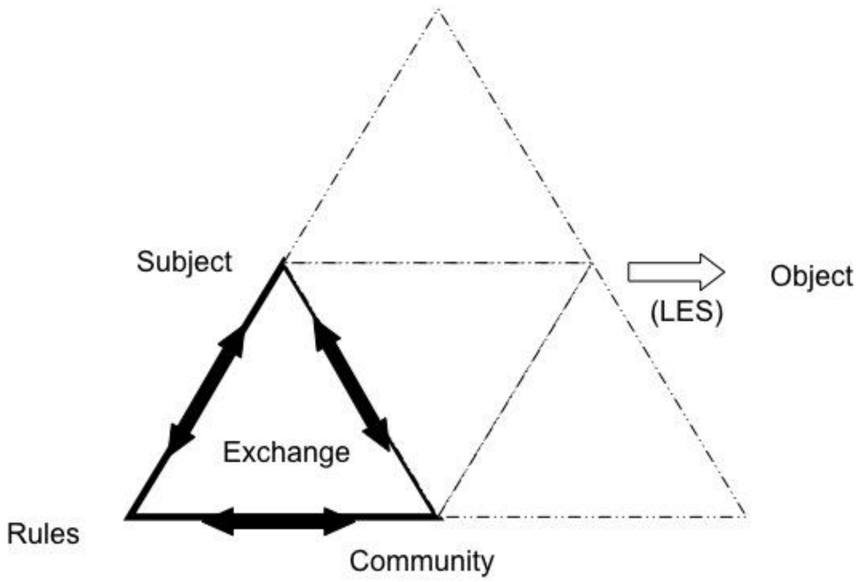

Figure 2. An example of a sub-triangle exchange (communication)

What we considered a third level of analysis consists of an analysis of an entire activity system illustrating the interrelations between the six poles at a certain time during the implementation of the LES. These activity systems are in fact transitional activity systems as we tried to capture their formation and transition along the development of the activity. Systems are the core of an individual's activity (e.g., any teacher or any other member of the school community). Describing an entire system at a certain time as the activity is unfolding offers the possibility of a more systemic and contextual reading so we can grasp the complexity of what is taking place. In this paper, we chose to present two activity systems that emerged from our analysis. The first one will illustrate how the teacher made it possible for the students to produce and exhibit their work on the theme of the *Awareness of the Risks of Tanning Salons*. The second activity system will provide an example of an action taken by some students following their classwork activities on the danger of electromagnetic UVAs and UVBs.

Finally, a fourth level of analysis juxtaposes two activity systems to show the interactions between the systems and the opportunity for expansive learning as illustrated in Figure 3 (Engeström, 2001). It also represents the specificity of the third generation. At this level, we illustrate how actors within the same community who share similar goals and motivations produce a new outcome. It also shows how the LES is not only produced but also exchanged among many actors of more than one activity system. "A collective activity system is driven by a deeply communal motive which is embedded in the object of the activity" (Engeström, 2000, p. 964).

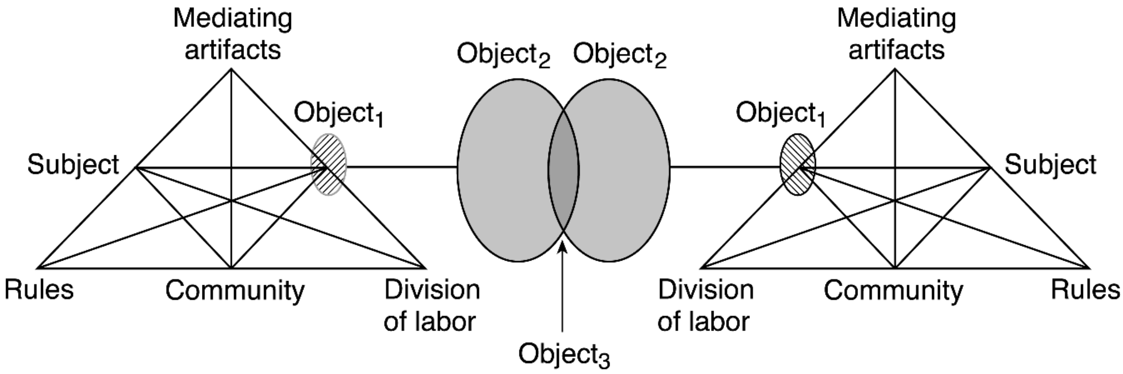

Figure 3. Two interacting activity systems as the minimal model. Third generation of Activity Theory (Engeström, 2001, p. 136).

Returning to the Two Research Questions

Further to the presentation of the case study, the analyzed data, and the chosen modes of analysis, it is important to point out to the reader that the findings presented in the following section may at times pertain to only one class or several classes, or may reflect the overall actions of the teacher throughout our four-month collaboration. In this contribution, we chose to highlight certain key moments in order to address the two research questions presented in the introduction. We felt that it was unrealistic to present each class in detail, as each one may independently constitute the basis of another study. We have already presented an overview of the nine classes that constituted the activity we analyzed. We also highlighted some of the teacher's lesson planning. In the result section, we will present how the content analysis of the students' concept maps, the interview's verbatim transcripts, and the summative evaluation have enabled us to identify the prescribed scientific concepts that were covered and evaluated during the nine classes.

Then we will move on to draw a portrait of some actions that were undertaken by either the teacher or some of her students (sub-triangular representation) and we will illustrate one of the transitional activity systems that we documented in order to bring light to the following question: "How does a high school science teacher engage in modeling and implementing an LES around a theme pertaining to *The Human Organism* in order to move away from a lecture base class?"

Table 3 highlights the analytical choices made in coherence with the planes of analysis and, in some case, with the corresponding classes.

Table 3. Pertinent CHAT analysis with corresponding planes of analysis

Relevant CHAT analysis	Corresponding planes of analysis
Content analysis	• Characterization of 6 poles (9 classes) • Determination of scientific concepts integrated in the theme (9 classes)
Sub-triangles	• Shared goals (subject-community-object) (Fig. 4) • Goals and actions (subject-division of labor-community) (9 classes) (Fig. 5) • Interindividual
Activity systems	• Production and exhibition of posters (Fig. 6) • Transitional activity system after Class 5 (Fig. 7)
Interacting activity systems	• Implementation of Class 1 (Fig. 8) • Interindividual

Results and Discussion

The Scientific Concepts Targeted by the nine-Class Activity

Let us start by presenting the list of scientific concepts that were mobilized during the activity as the participant was trying to let go of the stress related to the evaluation aspect of her teaching practice.

According to the new prescriptions of the Québec Education Program,

> *The theme for the first year of the cycle, The Human Organism, should be considered an integrative element and used as a basis for the assimilation of concepts related to other areas. For example, a study of the sense of sight can integrate a variety of concepts and knowledge such as the path of light inside the eye, the formation of images on the retina and the function of corrective lenses (QEP, 2006, p.33).*

As the participant began building around the chosen project, she was unaware which scientific concepts would be addressed by the activity.

> *I haven't made up my mind yet, but I would like to launch an awareness campaign on UV rays and produce a protective sunscreen with the kids to help protect their skin. To get there, I did a lot of research on the Internet and found certain activities that were already suggested. I was able to narrow my search down to the parts that interested me: the ozone layer, light spectrum, the colours of the rainbow, invisible light. I'm going to take the opportunity to make connections with geography: Why*

> *there are different skin colours, for example. Then, I will make connections with the classes they had in Secondary 2 on the solar system. That's the guideline so far; nothing is definite yet, but I would definitely like to talk about that and to analyze sunscreens as well.*[iii]

As the weeks went by, her objectives became more structured and her modeling and planning progressed. Table 4 presents the concepts covered in the activity that were drawn from the content analysis of the teacher's verbatim, the concept maps created by the students after Class 3, and the lesson planning prepared for Classes 2, 3, and 4 (see Table 1). Table 5 displays the entire summative evaluation that followed the theme-based activity.

Table 4. Concepts Identified Following the Analysis of the Interviews and Documents

Living World	nervous system, organ, tissue, hair, skin (characteristics, colour, functions, anatomy), melanoma, brain, eye, cancer, dermis, hypoderm, epidermis, transversal cut of the skin, moles, erectile muscles of the skin
Material World	frequency, wavelength, amplitude, electromagnetic spectrum, electromagnetic radiation, visible and invisible light, radio waves, mechanical waves, electromagnetic waves, UV, UV index, gamma rays, sunrays, radiant energy, vitamin D
Technological World	technological product design (sunscreen), product (moisturizing lotion, sunscreen), technological object (sunlamp)
Earth and Space	light properties, ozone layer, climate, regions of the globe at risk for skin cancer

Despite the fact that the teacher used an open-ended, theme-based approach for most of her nine classes, scientific concepts were very much at the heart of the activity. The summative exam supports this, as the questions go far beyond the sole appropriation of scientific concepts, such as infrared rays and the role of sensory organs (1-9, 12-14) in capturing light. The participant also asked her students to provide arguments to either defend the dermatologist's position or that of the tanning salon owner (10-11, 15-16). We observed that she was consistent with her goals as well as with those of her institution.

The Participant's Attitude and Goals in Relation to the Activity

Let us now focus on how she planned and implemented the nine classes that constituted the analyzed activity. It must first be said that according to the participating science teacher, tanning salons were increasingly popular among her school's female students, thus many actors of the school community who were aware of the potential dangers of UV radiation on their students' health were willing to collaborate with her to put an end to this trend. When she met with the dermatologist to share her concerns, the latter agreed to meet with her students despite his busy schedule. This was truly the flame that ignited her actions and made her think that a new way of teaching biology was indeed possible.

Table 5. Summative Evaluation of the LES-Related Concepts at the End of the Nine Classes

Julie has applied for a job in a tanning salon. She is ecstatic because she got the job and will therefore have access to free sessions. Her friend Manon is worried and therefore decides to inquire how the equipment works. Help her with this task.

1. (a) Two types of waves can be identified by their movement. Name them and briefly describe them. (b) There are two types of waves: mechanical and electromagnetic. What is the difference between these two types of waves?
2. What types of waves does the sun emit?
3. How can the following waves be described in terms of length and frequency? (a) Radio waves. (b) Gamma rays.
4. Which types of sunrays are responsible for tanning skin?
5. Which sunrays are responsible for the feeling of warmth on our skin?
6. Which one of the waves' characteristics corresponds to the quantity of energy that it carries?
7. It has been proven that UV rays can cause skin cancer. Why do we still need a small quantity of these types of rays?
8. UV rays that come from sunlamps or the sun itself affect the skin. Name one visible short-term and one visible long-term effect.
9. According to the information that you have gathered, how much sun exposure, in terms of time, do we need to stimulate the production of vitamin D?
10. Jonathan's mother has been visiting the tanning salon on a more frequent basis. She claims that it makes her feel better and that she could no longer do without. Is this possible?
11. Tanning salon owners claim that sunlamps provide a feeling of well-being. Consequently, can we argue that tanning salons are good for our health?
12. Our nervous system captures different types of stimuli that are redirected and processed by our brain. UV and infrared rays are not captured by our visual sensory organ. Which organ captures them?
13. A dermatologist explains the effects of tanning to a patient. She mentions that the skin is an organ of the nervous system and that it is divided into three structures: the dermis, the epidermis, and the hypodermis. In which structure are the sensory receptors located?
14. Other than the effects they have on the skin, UV rays can affect or damage another sensory organ. Which one?
15. Give two arguments that a dermatologist could invoke to lay blame on certain tanning salons for their lack of ethics.

16. Give two arguments that a tanning salon owner could invoke to defend the benefits of his establishment.

Our participant was fairly young at the beginning of her teaching career (five years of experience). She appeared to be highly motivated and dynamic and claimed that she could not see herself implementing the same curriculum year after year.

> *I'm also more at ease with the content and, in the beginning, I was insecure and had a tendency to stick closely to the teaching system I had experienced as a student, such as in math and science classes. There'd be a little bit of theory [followed by] exercises and it was the same thing during the following classes – [it was] the same routine in every class…. At the beginning of the [school] year, I was OK with doing things that way, but then later I found myself to be really dull to be continually teaching that way. I said to myself, "There's no way my career is going to be like that! I'm going to have to be motivated and change my teaching strategies." It was at that point that I expanded my horizons and realized that there was a ton of resources around me, but [at the same time] there was more than just my textbook and my exercise booklet.*[iv]

Also critical about her academic background, the participant pointed out that in the context of science teaching, she did not want to provide her students with simple recipes and prewritten protocols for their lab work. She expressed being very concerned about the need to contextualize her practice. She saw her students as intellectually evolving entities. She also had a humanist vision of science teaching, in the sense that her objective was to help her students to develop their personality, thus helping them better understand and adapt to their surrounding environment (Barma & Guilbert, 2006). Developing critical thinking was also important to this teacher, and the issue pertaining to tanning salons was, in her opinion, an opportunity to help her students become more aware of the various circumstances surrounding this dilemma, which in return would ultimately lead them to make more informed decisions about their health. She also complied with the new curriculum: Development of disciplinary competencies: Competency no. 1 (Classes 2 and 9); Competency no. 2 (Classes 3, 4, 5, and 8); Competency no. 3 (Classes 1, 6, 7, and 8).

> *The overarching educational project of the high school is to develop students' capacity for critical thinking and their autonomy, to enable them to make sound choices; that's the kind of education we're going to do with this presentation.*[v]

The data shows that the symbolic and material tools that were mobilized in the participant's planning or in class with the students were both numerous and diverse. Informational resources consisted of magazines, newspaper articles, other media, Web sites, scholastic manuals, pedagogical material, ministerial documents such as the Québec Education Program, and LES models, the latter referring to open teaching approaches as controversies, debates, problem solving, software (concept maps), and various courses she attended related to the new Program. Material resources included lab equipment, posters, various materials for lab experiments at home or in the students' community, computers, etc.

In the teacher's preparation of nine different classes on the theme *Awareness of the Risks of Tanning Salons*, the community members with whom she interacted were numerous and not limited to her school's teaching staff. Regarding the rules and the division of labour, several implicit or explicit habits were amended, and thanks to a generous collaboration on the part of community members (students, parents, dermatologists, a beauty sales consultant, other teachers, a lab technician, a computer technician, the principal, a student's supervisor, a pharmacist), the science teacher managed to successfully implement her activities.

The following verbatim transcript excerpts illustrate how this collaboration took form and was actualized, namely through: support from members of the curricular and extracurricular activities team; support from colleagues; involvement of a pharmaceuticals expert, etc.

> ***The expert** is going to come during the second period – meaning, once we've done the concept using the article on the different colours of skin. On this point, I spoke with the **special activities team**, who are going to help me with the publicity, so as to make sure as many people as possible come during lunch time. So I'm going to make a small draft of the different words I want to have on my poster, and Ms. ..., from **special activities**, will use the Master software to produce a nice poster; I've got her to collaborate on this.*
>
> *I've also got **Mr. Z,** who's going to take care of the **technical side of things** – meaning, the computer, the projector – since the **specialists** are going to have a PowerPoint presentation to support their talk. I want to be sure and have a talk that's going to affect **students** and, above all, it's going to be a broad subject (Document 'Subject 4', Section 1, Paragraphs 41-44).*
>
> Then, narrating how the dermatologist's talk proceeded, she added:
>
> *[**the dermatologist]** met **all the students at the school** who were interested in attending the talk; I'd say there were approximately 40 students; in the afternoon, **all my Grade 9 students** were there, with the exception of one group that couldn't attend. So three out of four groups were in attendance, with the remaining group taking a test in the gym*
> *(Document 'Subject 5a', Section 1, Paragraph 6).*
>
> *My **former colleagues** were also there, even if I'm the only one who's teaching Grade 9 Science and Technology; I talked a lot with **X, who teaches Science and technology** during the second year of Cycle 1.*
> *(Document 'Subject 11', Section 1, Paragraphs 117-118)*
>
> *There was a **researcher for the pharmaceutical laboratories** who was on hand; some prizes were drawn – samples of sunscreen – and the **students** were really excited about all that* (Document ' Subject 5a', Section 1, Paragraph 8).

It was clear from our analysis that this teacher demonstrated a flexible planning process and displayed an unwavering confidence in the face of uncertainty while respecting the principles of the new reform. She also specified that she had the full backing of her principal and the members of her science teaching department. The next excerpts show how the responsibilities were shared:

> *The principal appointed resource people as B and C. They took part in training sessions, and the principal and these teachers got together to share information. We really worked as though we were the students and they were the teachers…And they truly presented us with a Learning and Evaluation Situation* (Document 'Subject 4', Section 1, Paragraph 92).

And how collaboration occurred between departments and the persons in charge of training at the school:

> *Each member of the various departments worked on developing a learning situation specific to their field; following this, we submitted the outcome of our work to B or C* (Document 'Subject 4', Section 1, Paragraphs 98-99).

In summary, it was interesting to witness the impressive level of collaboration and consensus among many members of the school community. In addition, few problems were identified by the participant, and the open attitude of the school staff members and the outside actors involved made it such that all of the problems were promptly dealt with. This experience thus enabled the science teacher to renew her teaching practices.

The shared object: toward implementation of the LES and a form of collaboration between members of the community

Within the context of pedagogical renewal in science and technology, and in light of the participant's desire to innovate her practice, the previous data show the importance of interrelations between the principal, the science teacher, and other teachers in her school.

The two sub-triangles (Figure 4 and 5) we selected are intended to illustrate the systemic relationships between certain poles of the sub-triangles. They will subsequently aid us to model full triangles as well as the zone of proximal development occurring between them. Pursuing the same object – i.e., supporting the teacher in her efforts to change her teaching approach – thus appears to be shared (see Figure 4). It should be pointed out that the distribution of actions and operations within the school community was both negotiated and flexible under the curricular changes.

As was presented in the preceding section, during one of the interviews, the participant claimed that the pedagogical professional development director of the school had made real efforts to put together special "pedagogical theme days" for all of the teachers well before the MELS began offering training courses on implementing the new curriculum. Some teachers (French, Geography, Math, etc.) were mandated to attend professional development courses outside of school, and upon their return had the responsibility to become promoters by sharing the knowledge acquired during their training with their colleagues. This was completed during regular PD days within the school calendar. The participant in our study was open and enthusiastic about sharing information with her colleagues, both inside and outside of her particular department. Hence, her motivation to innovate in the context of pedagogical reform had increased.[vi]

Figure 5 provides an example of how the division of labour changed. The tasks and responsibilities were horizontally and vertically redistributed: some teachers saw their status changing as they became resources for their peers. When the principal delegated her authority by providing new information to some of the teachers, thereby enabling them to change their status with respect to their peers, roles were modified.[vii] As the principal accepted to share her expertise, the balance of power was altered. Thus when the time came to share the information with the other teachers, our participant claimed that she felt like a student again and was quite willing to comply with various activities to eventually master the new curriculum. Moreover, when our participant was asked to describe the school's general atmosphere with respect to the new education program, she pointed out that it was generally very positive.

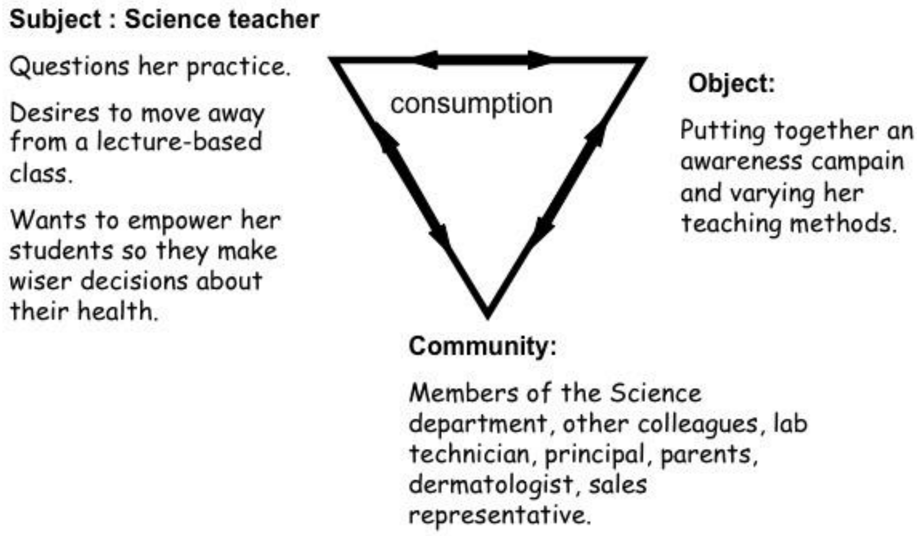

Figure 4. "Subject-community-objet" sub-triangle

Two emerging activity systems: Production and exhibition of posters and Action taken by some students following Class 5

The third level of analysis enables the activity system's operation to emerge at a specific point during the activity (LES), meaning that it makes it possible to explain how the six poles of a system are interrelated at a certain time. Roth, Lee and Hsu (2012) prefer to speak of moments rather than poles. As was previously presented in the theoretical framework, the minimum unit of analysis in activity theory is an entire system, which implies respect for the dialectical aspect specific to activity theory: such moments or elements are mutually interdependent and cannot exist unless all are present.

In the following examples, the activity systems illustrate how 1) the teacher went about getting her students to produce and present the integration of their work in a public space (class 9) and 2) how some of these students engaged in an action following the presentation given by the dermatologist and Class 5 (sunscreen sample analysis).

The chief interest of presenting Figure 6 is to be able to more fully grasp how activity theory has the potential to enable us to envision the transformation of science education practices. Following forward with the work of Vygotsky (1985), it shows how one can proactively change the conditions framing learning activities. This activity system offers an example of an attempt to transform an essentially lecture-based teaching practice and to shift toward a variety of approaches; it is also illustrates a degree of distance being taken toward the production/reproduction of courses that are always prepared ahead of time. For this Grade 9 science teacher, developing nine courses differently on her own brought into play a whole other register of actions and collaboration. Paradoxically, by accepting this insecurity, she enhanced her feeling of competency, as she succeeded in implementing a public activity in which her students shared their constructed knowledge. These results are in keeping with the propositions of Roth et al. (2012), who call on us to rethink and empower science teaching by implementing new tools of mediation in the of teaching/learning context.

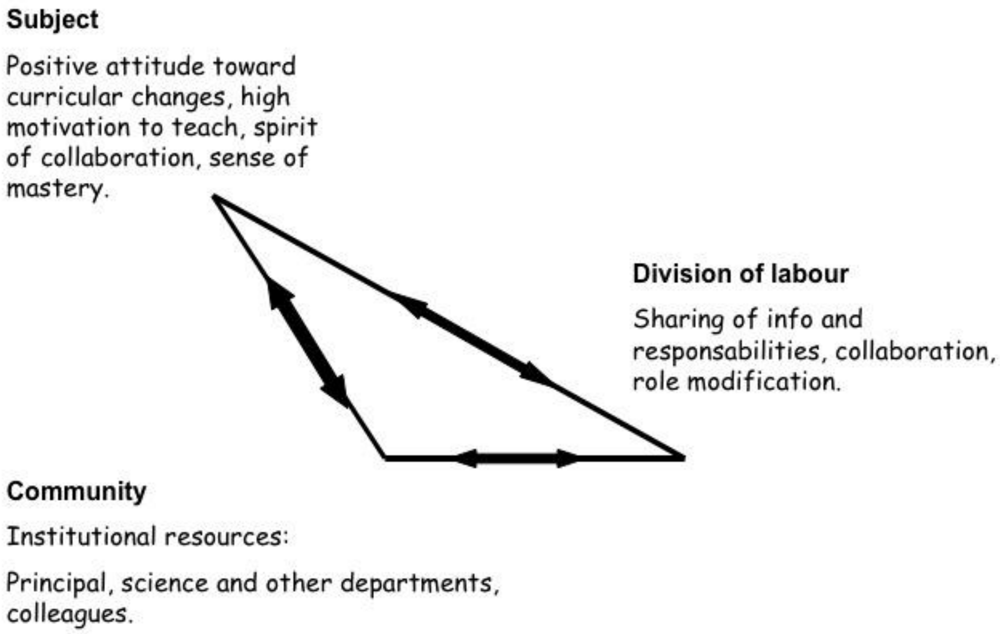

Figure 5. "Subject-division of labour-community" sub-triangle

The systematic analysis and interpretation of this system provides us with several points of interest for guiding teachers who seek to change their approach. The shared object was the implementation of an awareness campaign concerning tanning salons, a topical subject as well as a genuine problem in this teacher's school. She made a priority of leaving her textbook to one side and doing things differently. Thanks to the collaboration of members of the administration, several of her colleagues and some external experts, she was able to carry out her LES (Barma, 2010). These results support those of Sannino and Nocon (2008), who have asserted that any change in education will necessarily involve a wide-ranging form of collaboration that extends beyond the classroom. As part of facilitating the production of posters by students, the information was shared in the school. These posters represent a change in the vertical distribution of powers and statuses: in effect, students enjoyed a greater degree of freedom and played a more active role in their learning process. We are coming closer to a teaching practice that makes more sense for them and that will hopefully enable them to become more fully involved and critical citizens (Parsons, 2009). This open-ended, integrated and contextualized LES meant that students did not all do the same tasks at the same time. Here we have an example of a change in practice for the science teacher who took part in the present research project.

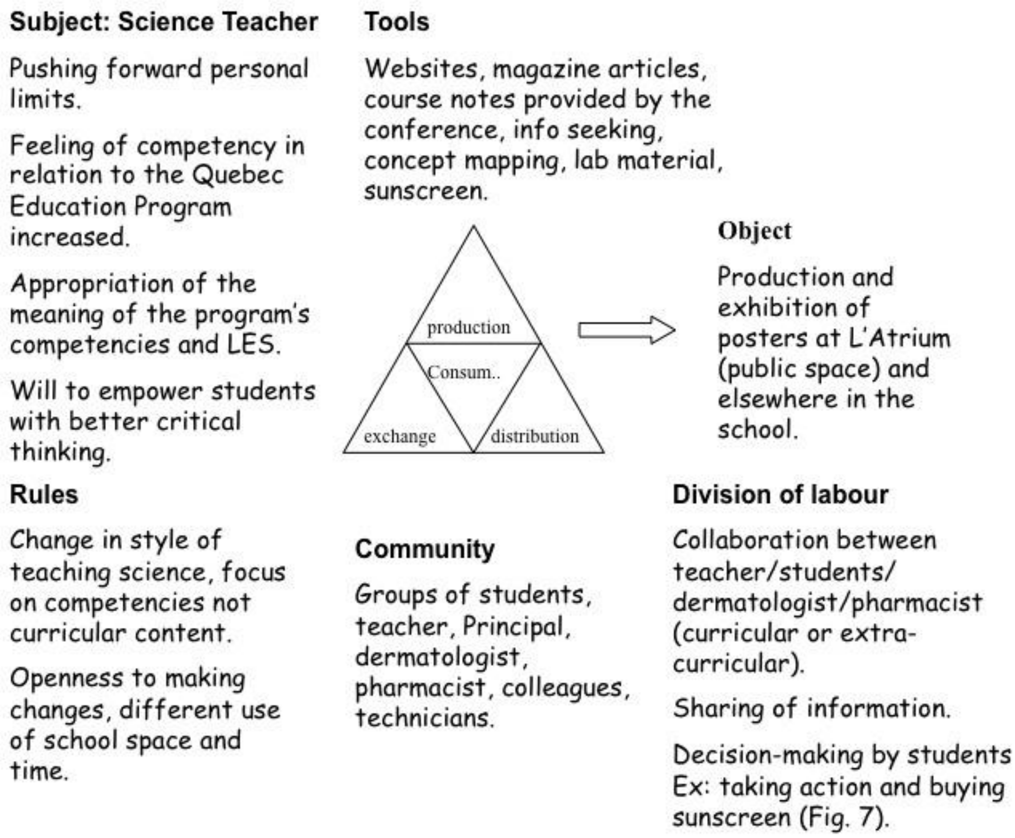

Figure 6. Activity system. Production and exhibition of posters

The next activity system we present offers a valuable illustration of how what is produced by one activity system can often generate another such system. The subjects involved in the activity of this system (Figure 7) were a half-dozen students who decided to go to a pharmacy with their parents after hearing the dermatologist's presentation and analyzing the sunscreen samples in the lab (Class 5). Feeling concerned about the effects of UV rays on their skin, these students asked their parents to go with them to the local pharmacy to buy sunscreen: "Because on Monday morning, a lot of people told me: Ma'am, I bought some sunscreen this weekend with my parents. I think there is a strange spot and I wish it could be part of our annual checkup. I think that there are a lot of moles and I wish that closer attention could be paid to them" (Document, Subject 5a, Section 1, Paragraph 19).

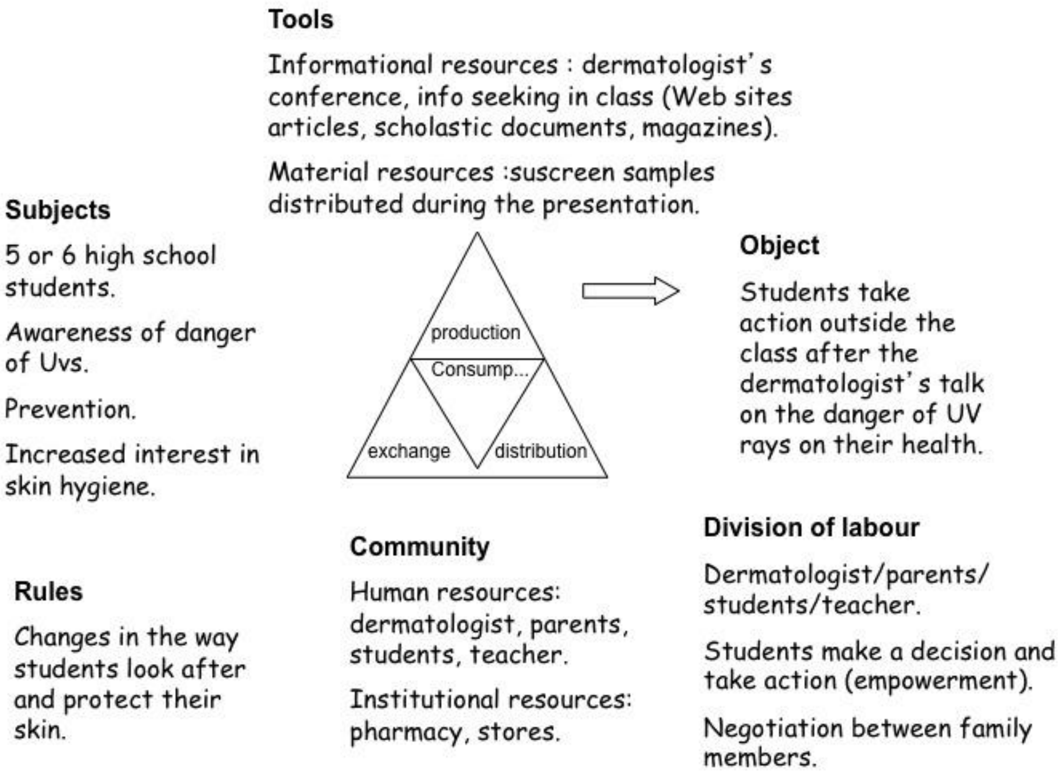

Figure 7. Activity system. Students acting outside the classroom

To show how the teacher's actions could lead to a decision on the part of the students, the following excerpt offers an illustration of a classroom information search task that was aimed at developing understanding of the links between the skin and electromagnetic rays:

> *The students understand that they mustn't become paranoiac, but that it's an element of our environment. You can't live without the sun and, in order to live with it, you have to use some protection. So, I chose an article from the July 2004 issue of "Science et vie junior" that follows the historical evolution of various skin colours. We're talking about six million years down to the present time. I asked them individually to read this four-page article, which does a good job of popularizing its subject. Working from this article, they created a bank of words, and then I asked them to make a conceptual network – a network that explains scientifically, and historically, the existence of different colours. Once everybody had done that, the students exchanged their work with one another and filled in the concepts that hadn't been taken into account. The activity that comes afterward will deal with the*

> *electromagnetic spectrum: what is the spectrum? In it, we'll go as far as radio waves and gamma waves, which have a very short wavelength and high frequency.*

The LES set up by the science teacher therefore generated another activity system, namely, students sharing some of their concerns with their parents regarding skin care. The outcome of this activity system was the act of going to the pharmacy with the parents to buy protective sunscreen. As it occurred outside of the school after the presentation, this action may be read within the context of the various interactions that led to its production and subsequent fruition in the community.

As documented in the verbatim material, all of the students were given sunscreen samples provided by a beauty parlor representative on the day of the presentation.[viii] This increased the students' interest and awareness regarding the necessity of protecting their skin from potential damage that may result from prolonged exposure to UV rays. By agreeing to accompany their children to a local pharmacy, the parents became an important element in the construction of a new activity at another context level outside the school boundaries. The fact that some students had decided to look after their skin led to yet another context level, which was something the science teacher could not have foreseen. This issue can therefore be extended to a broader context: the family and the impact of Class 1 (the conference given by the dermatologist) on members of some families. "…What students do makes immediate practical sense within the larger pursuit of an activity that already constitutes an intelligible part of the world" (Roth et al., 2012, p. 137).

The students expressed to the teacher their intention to modify their habits at home and to incorporate skin care and skin protection into their daily routine. This is perceived as a modification of explicit rules at home. Here, a brief explanation of the concept of rules, as described by Leont'ev (1978), is necessary. According to this author, rules are linked to the conditions of realizing when an operation takes place in a certain context; they are thus seen as being oriented toward the action being undertaken. In the previous example, this action depends on a given goal (protecting one's skin) and is oriented toward a broader horizon which is situated at another context level (the family).

Even though it is impossible to predict the types of interactions that take place within families, it can be assumed that the students' contribution of new information to their family may have triggered interesting conversations. This was most likely the case here, as the students had shared information that was acquired in school.

As far as the aspect of symbolic and material tool mediation is concerned, the present analysis highlights both the material and informational resources, as the students' appear to have gained greater awareness of the dangers of UV radiation on their skin.

Consumption of the object (buying sunscreen), which made the outcome possible, occurred because certain motivated students had access to human resources (dermatologist, teacher, parents) and institutional resources (pharmacy, shopping center) within their community. The actions undertaken by these students were distributed within their community through a redistribution of actions between students, parents, teachers, and the dermatologist. The students became more empowered and thus in this case the knowledge building is an example of distributed cognition among members of the community. These results fall in the footsteps of promising research centred on organizational learning; individual actions transform both individuals and the activity system (Virkkunen and Kuutii, 2000).

Using interacting activity systems to illustrate the potential for collective negotiation

We have chosen to present the following results as they serve to validate our response to the first research question by illustrating how the implementation of Class 1 was possible because of the collaborative efforts of several members of the educational community.

The fourth level of analysis is achieved by juxtaposing two activity systems and by illustrating how the two systems share certain boundaries and how problems are solved collectively. These two systems share the same outcome and, as will be pointed out, “the object or the motive of the activity is reconceptualized to embrace a radically wider horizon of possibilities than in the previous mode of activity” (Engeström, 2001, p. 7). For this purpose, the activity of the dermatologist and that of the science teacher takes place by having the presentation focus on the theme of the danger of UV rays on the skin.

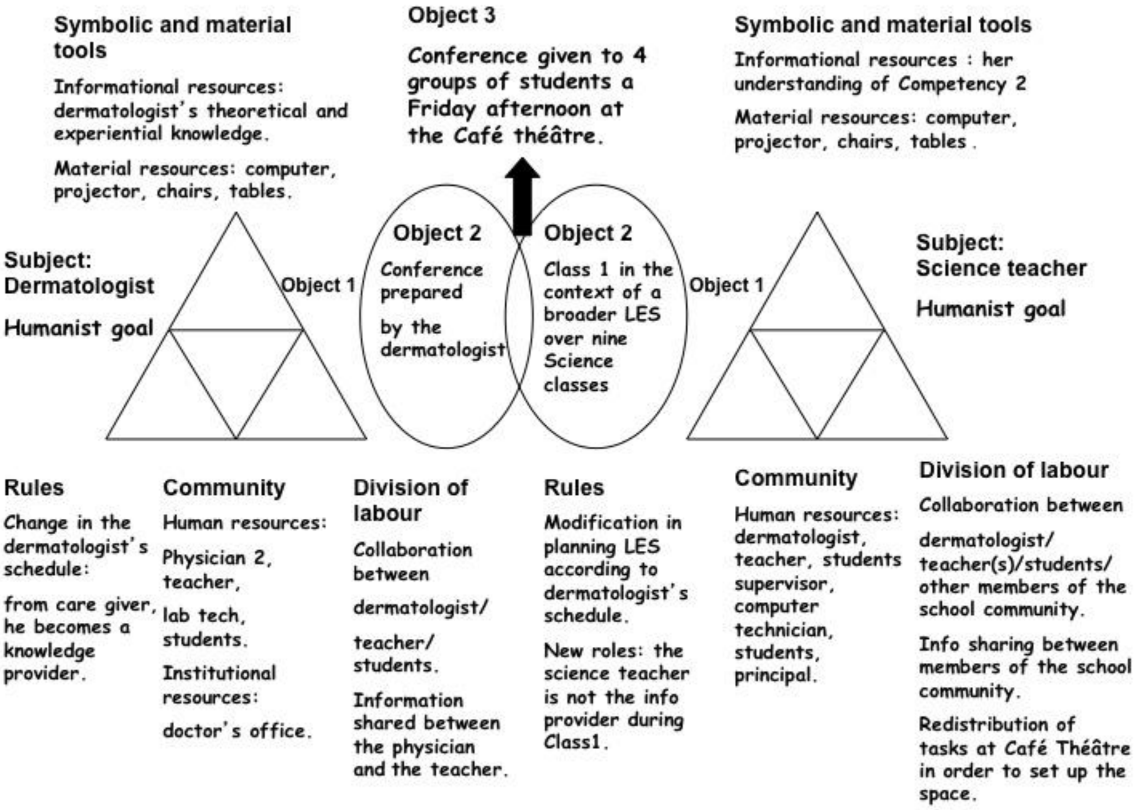

Figure 8. Two activity systems sharing the same object: organizing a talk. Teacher’s and dermatologist’s activity

The first activity (Class 1) planned by the science teacher was a talk given by a dermatologist whom she had met by chance at a medical clinic. The teacher explained to him her intention to inform her students and to help them become more aware of the dangers of tanning salons. The first activity system, presented above, which refers to the production of a presentation for high school science students, is the activity of the dermatologist. The activity was held on a Friday afternoon outside the usual class schedule to accommodate all of the students. It was decided that this activity would be linked to the science teacher's activity, which was the planning of her first activity in the context of a broader project extended over nine classes.

In both cases, what was identified as Object 1 did not reflect the activity that was to occur (the dermatologist's presentation) but rather an initial state of unreflected, situationally raw material which would eventually become a key object representing the imminent outcome. This outcome (Object 3) was collectively negotiated by all of the community members involved in the project. In the present example, the focus is on the challenges and possibilities of inter-organizational learning.

Object 1, for the dermatologist, represents the preparation of his lecture. For the teacher, Object 1 was the planning and implementation of the first class activity in the context of a broader group of nine science classes. As mentioned, at this point it remained the goal-oriented activity that would transform the learning environment.

In both cases, each activity system moved toward Object 2 (the dermatologist's construct of how he foresaw his presentation and negotiated it in its own activity system, and the teacher's vision of how this lecture would take place) and became essential for the school community, as each activity system's boundaries interrelated, were co-constructed, and negotiated the outcome of the lecture.

These "Object 2s" were negotiated by all of the actors in both systems and was mediated by symbolic and material artifacts. As indicated in Figure 6, there was a focus on the way the participant understood the new science and technology program, particularly with respect to how she perceived Competency no. 2 (symbolic tools). In her opinion, developing this competency would enable students to justify and qualify their opinion on the issue of the *Awareness of the Risks of Tanning Salons*. It is in pursuing this goal that she invited a dermatologist to come in and discuss this issue with her students. It was therefore crucial for her to mobilize an external resource. Expanding her teaching practice meant searching for the most appealing resources directly in the community for this particular context. Similarly, for the dermatologist, the essential tools mediating his activity were his theoretical and experiential knowledges which would eventually be shared with the science students.

What was identified as Object 3 (the presentation that actually took place) emerged from the interconnected activities of both systems rather than from each subject's individual goals and motivations; on the contrary, it had to be considered as a product of an ongoing negotiation process that took place between human and non-human actors within both systems. Object 3 was therefore the product of moving objects (1 and 2) generated by actions and operations in both activity systems.

What Engeström (2001) identifies as expansive learning (the transformation of the learning environment) is a culturally produced activity that creates new patterns of activity. With respect to the dermatologist's presentation, the fact of obtaining the support of several members of this teacher's educational community enabled her to teach in a different way. The dermatologist, the principal, and the other teachers who rearranged their class schedules all contributed in their own way to transforming the students' learning environment on a Friday afternoon. In the present case study, we witnessed very little contradictions within this learning environment. Any problems that arose were promptly resolved, as most of the persons involved were willing to collaborate and support the science teacher in her efforts to innovate her practice in the context of the ministerial reform.

As shown in Figure 8, the division of labour in both activity systems created new roles for the participants, each one contributing their own history and motivation. Figure 8 also shows multiple layers within this community. The dermatologist and the teacher shared information and their respective tasks subsequently changed; the doctor became a knowledge promoter and the teacher was able to transfer her influence to the dermatologist. For the activity to be successful, many teachers within the school agreed to cancel their regular classes and allow their students to attend the presentation during which the dermatologist openly interacted with the students. Because the activity took place in an area where students usually spent their lunchtime, many members of the school community collaborated in preparing this space for the meeting.

Our data analysis supports a sociocultural posture, as it illustrates the systemic dimension of the co-construction of meanings. The entire activity system which constitutes the unit of analysis and the creation of new constructs (outcome) is possible inasmuch as goals are shared by actors within the two systems, namely, the dermatologist, the teacher, the students, the technician, the students' supervisor, and other teachers.

Conclusion

Centering a learning and evaluation situation (LES) on the theme *Awareness of the Risks of Tanning Salons* made it possible for the science teacher to change (at least momentarily) her pedagogical approach to enable the students to learn an alternative investigative process in the lab (open inquiry), consult experts, and seek relevant information without disregarding the importance of the scientific concepts related to the theme. In light of our findings, it thus appears possible for a teacher to use an actual life situation experienced by the students to develop and integrate a new teaching sequence. It appears that the prescriptions of the Québec Ministry of Education (Government of Québec, 2006) to present students with contextualized, open-ended and integrated situations hold promise for achieving what van Eijck (2009) has proposed – namely, a more authentic, meaningful kind of science. The fourth level of analysis supports the principle of Expansive learning (Engeström, 1987) and illustrates two activity systems that share the same object and that provide a basis for implementing what the science teacher qualifies as an innovation.

A more detailed analysis of how the entire activity progressed (nine classes) provides a much better understanding of the importance of collaboration between colleagues in contributing to the appropriation of certain principles of the proposed curricular reform such as theme-based teaching and schools that are more open to the community around them. The many concepts covered and evaluated throughout the project support the potential of such an approach, in keeping with Beane (1997)'s comments. Will the teacher continue to appropriate the reform? Further investigations are required to document how her teaching practices evolve. However, the adoption of a sociocultural framework like that of activity theory has enabled us in our capacity of teachers to reflect on different ways of teaching science and to make the shift toward collective engagement when the issue involves one's personal health or environmental policies (Roth et al., 2012).

In the context of educational reform in science and technology, we were able to identify a variety of elements that enabled a new LES to take place that facilitated collaboration between the various actors in the community and confirmed the importance of sharing common goals.
Given the current context in secondary schools in Québec, the knowledge acquired through our study is highly relevant and could be re-invested in university training and professional development programs for teachers; it also follows forward with the proposals of Nocon (2008) to promote changes in education. According to Engeström & Suntio (2002), students are the best agents of their learning process, and primary and secondary teachers should set up activities that are not only stimulating but that also develop their students' autonomy.

References

Aikenhead, G. S. (2004). *Science-based occupations and the science curriculum: Concepts of evidence*. Retrieved from: http://www.Interscience.wiley.com

Barma, S. (2011a). A sociocultural reading of reform in science teaching in a secondary biology class. *Cultural Studies of Science Education*, 6*(3)*, 635-661. doi: 10.1007/s11422-011-9315-9

Barma, S. (2011b). Analyse d'une démarche de transformation de pratique en sciences dans le cadre du nouveau programme de formation pour le secondaire, à la lumière de la théorie de l'activité. *Revue canadienne de l'éducation*, *33*(4), 677-710.

Barma, S. (2008a). Vers une lecture systémique du contexte, des enjeux et des contraintes du renouvellement des pratiques en éducation aux sciences au secondaire au Québec. *Revue canadienne des jeunes chercheurs en éducation, 1*(1).

Barma, S. (2008b). *Un contexte de renouvellement des pratiques en éducation aux sciences et aux technologies : une étude de cas réalisée sous l'angle de la théorie de l'activité*, Université Laval, Québec.

Barma, S. (2007). Point de vue sur le nouveau programme Science et technologie du secondaire au Québec : regards croisés sur les enjeux de part et d'autre de l'Atlantique. *Didaskalia,* Paris, *30*, 109-137. [ISSN 1250-0739], doi : 10.4267/2042/23968.

Barma, S. et Guilbert, L. (2006). Différentes visions de la culture scientifique et technologique : défis et contraintes pour les enseignants. Dans A. Hasni, Y. Lenoir et J. Lebeaume (dir.), *La formation à l'enseignement des sciences et des technologies au secondaire dans le contexte des réformes par compétences* (p. 11-39). Québec : Presses de l'Université du Québec.

Beane, J. A. (1997). *Curriculum integration: Designing the core of democratic education.* New York: Teacher's College Press.

Bracewell, R. J., Sicilia, C., Park, J., & Tung, I.-P. (2007). The problem of wide-scale implementation of effective use of information and communication technologies for instruction: Activity theory perspectives. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago.

Brandt-Pomares, P., Aravecchia, L., Bally, J., Buisson-Fenet, E., Conio, M., & François, N. (2008). Comment former des enseignants pour une éducation à l'environnement et au développement durable. *Aster, 48*, 205-229.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42.

Charmaz, K. (2005). Grounded theory in the 21st Century. Applications for advancing social justice studies. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage Handbook of Qualitative Research* (3rd ed.) (pp. 507-535). Thousand Oaks, CA: Sage Publications.

Class, B. (2001, 25/9/01 by DKS). Introduction de l'innovation technologique dans l'éducation. Technologie Internet et Éducation. Last retrieved on Dec 09, 2010, http://tecfa.unige.ch/guides/tie/html/innovation/innovation.html

Denzin, N. K., & Lincoln, Y. S. (Eds.) (2005). *The Sage Handbook of Qualitative Research*. Thousand Oaks, CA: Sage Publications.

Edwards, A. (2008). Activity theory and small-scale interventions in schools. *Journal of Educational Change, 9,* 375-378.

Engeström, Y. (1985). The emergence of learning activity as a historical form of human learning. Tidskrifffför NordiskFöreningförPedagogiskforskning, 5, 12–20.

Engeström, Y. (1987). *Learning by expanding: An activity-theoretical approach to developmental research*. Helsinki, Finland: Orienta-Konsultit.

Engeström, Y. (1999). Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen, & P. R.-L. (Eds.), *Perspectives on activity theory* (pp. 19-38). Cambridge University Press.

Engeström, Y. (2000). Activity theory as a framework for analyzing and redesigning work. *Ergonomics*, *43*(7), 960-974.

Engeström, Y. (2001). Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of Education*, *14*(1).

Engeström, Y. (2008). Weaving the texture of change. *Journal of Educational Change Activity Theory and School Innovation*, *9*(4), 379-383.

Engeström, Y., Engeström R., & Suntio, A. (2002). Can a school community learn to master its own future? An activity theoretical study of expansive learning among middle school teachers. In G. Wells & G. Claxton (Eds.), *Learning for life in the 21st Century* (pp. 211-224). Oxford, UK: Blackwell.

Fourez, G., Maingain, A., & Dufour, B. (2002). *Approches didactiques de l'interdisciplinarité.* Brussels, Belgium: De Boeck Université.

Government of Québec (2006). Science and technology. Secondary cycle two. Québec: Ministère de l'Éducation du Loisir et du Sport. Retrieved from http://www.meq.gouv.qc.ca/sections/programmeFormation/secondaire2/medias/en/6c_QEP_ScienceTechno.pdf

Hartley, D. (2009). Education policy, distributed leadership and socio-cultural theory. *Educational Review 61*(2), 139-150.

Hodson, D. (1999). Going beyond cultural pluralism: Science education for socio-political action. *Science Education, 83*, 775-796.

Latour, B. (1993). Ethnography of a high-tech case: About Aramis. In P. E. Lemonnier (Ed.), *Technological choices: Transformation in material cultures since the neolithic*. London: Routledge.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.

L'Écuyer, R. (1990). *Méthodologie de l'analyse développementale de contenu.* Sillery, QC: Presses de l'Université du Québec.

Lee, S. (2011). More than just story−telling: cultural–historical activity theory as an under−utilized methodology for educational change research. *Journal of Curriculum Studies,* 43(3), 403-424.

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching, 38*(3), 296-316.

Leont'ev, A. N. (1978). *Activity, consciousness, and personality]* (M. J. Hall, Trans.). Englewood Cliffs, NJ: Prentice-Hall.

McGinnis, J. R., & Simmons, P. (1999). Teachers' perspectives of teaching science-technology-society in local cultures: A sociocultural analysis. *Science Education, 83*, 179-211.

Méheut, M. (2006). Recherches en didactique et formation des enseignants de sciences. In Commission européenne. Direction générale de l'éducation et de la culture (Eds.), *L'enseignement des sciences dans les établissements scolaires en Europe. États des lieux des politiques et de la recherche* (pp. 55-76). Brussels, Eurydice.

Miettinen, R. (2006). The sources of novelty: A cultural and systemic view of distributed creativity. *Creativity and Innovation Management*, *15*(2), 173-181.

Murphy, E., & Rodriguez-Manzanares, M. A. (2008). Using activity theory and its principle of contradictions to guide research in educational technology. *Australasian Journal of Educational Technology*, *24*(4), 442-457.

Nocon, H. (2008). Contradictions of time in collaborative research. *Journal of Educational Change, 9*, 339-347.

Osborne, J. (2003). Attitudes towards science: A review of literature and its implications. *International Journal of Science Education, 25*(9), 1040-1079.

Page, R. (1987). Teacher's perspective of students: A link between classrooms, school cultures, and the social order. *Anthropology and Education Quarterly, 18,* 77-99.

Parks, S. (2000). Same task, different activities: Issues of investment, identity and use of strategy. *TESL Canada Journal, 17*(2), 64-88.

Parsons, E.C. (2009). Revisiting and reconsidering authenticity in science education: Theory and the lived experiences of two African American females. In W.-M. Roth (Ed.), *Science education from people for people : Taking a (stand) point* (pp. 22-38). New-York: Routledge.

Roth, W.-M. (2006). Étudier la pratique enseignante dans sa complexité : une exigence pour la recherche à la formation à l'enseignement. In A. Hasni, Y. Lenoir, & J. Lebeaume (Eds.), *La formation à l'enseignement des sciences et des technologies au secondaire. Dans le contexte des réformes par compétences*. Québec, QC: Presses de l'Université du Québec.

Roth, W.-M. (2009). On the inclusion of emotion, identity, and ethico-moral dimensions of actions. In A. Sannino, H. Daniels & K. Gutierrez (Eds.), Learning and expanding with activity theory (pp. 53–74).Cambridge, UK: Cambridge University Press.

Roth, W.-M., & Calabrese Barton, A. (2004). *Rethinking scientific literacy*. New York: Routledge Falmer.

Roth, W.-M., & Lee, S. (2004). Science education as/for participation in the community. *Science Education, 88,* 263-291.

Roth, W.-M., Lee, Y.-J. & Hsu, P.-L. (2009). A tool for changing the world: possibilities of cultural-historical activity theory to reinvigorate science education. *Studies in Science Education, 42*(2), 131-167.

Sannino, A. (2011). Activity theory as an activist and interventionist theory. *Theory and Psychology*, *21*(5), 571-597.

Sannino, A., & Nocon, H. (2008). Introduction: Activity theory and school innovation. *Journal of Educational Change, 9,* 325-328.

Sawchuk, P. H., Duarte, N., & Elhammoumi, M. (2006). *Critical perspectives on activity: Explorations across education, work and everyday life*. New York: Cambridge University Press.

Stake, R. (1995). *The art of case research*. Newbury Park, CA: Sage Publications.

Tobin, K., Tippins, D. J., & Gallard, A. J. (1994). Research on instructional strategies for teaching science. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 177-210).

Tsai, C.-C. (2001). A science teacher's reflections and knowledge growth about STS instruction after actual implementation. *Science Education, 86*(1), 23-41.

Urgelli, B. (2008). Éducation aux risques climatiques : premières analyses d'un dispositif pédagogique interdisciplinaire. *Aster, 46, 97-121.*

van Eijck, M. (2009). Scientific literacy: Past research, present conceptions and future developments. In, W.-M. Roth & K. Tobin (Eds.), *The world of science education: Handbook of research in North America* (pp. 245-258). Rotterdam: Sense Publishers.

Virkkunen, J., & Kuutii, K. (2000). Understanding organizational learning by focusing on 'activity systems'. *Accounting management and Information Technologies, 10,* 291-319.

Vygotsky, L. (1985). *Pensée et langage* (F. Sève, Trans.). Paris: Messidor/Éditions sociales. [Also published in English as *Thought and Language* (revised edition, 1986). Cambridge, MA: The MIT Press].

Yamagata-Lynch, L. C. (2007). Confronting analytical dilemmas for understanding complex human interactions in design-based research from a Cultural-Historical Activity Theory (CHAT) framework. *The Journal of The Learning Sciences*, 16(4), 451-484.

Yamazumi, K. (2008). A hybrid activity system as educational innovation. *Journal of Educational Change*, *9*, 365-373.

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Notes:

[i] These students did not participate in the present study, but we would like to point out that the teacher also had a teaching assignment at this level.
[ii] The concept of transitional activity systems was brought up by Engeström in August when one of the authors attended seminars at the CRADLE in Helsinki. These systems aim to describe the development of the activity at a given time but are constantly changing.
[iii] Document 'Subject 3', Section 1. Based on raw data analyzed with the Nvivo 2software.
[iv] Document 'Subject 1', Section 1, Paragraphs 89-102.
[v] Document 'Subject 2', Section 1, Paragraphs 42-47.
[vi] Document 'Subject 1', Section 1, Paragraphs 235-236.
[vii] Document 'Subject 4', Section 1, Paragraph 93.
[viii] “Most girls tried their samples” (Document Subject 5a, Section 1, Paragraph 19).