# The Chemistry Teaching and Indoor Air Quality: Analysis of a STS Thematic Approach

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The proposals of approaches that encompass the science, technology and society (STS) interactions have been shown as an alternative to aid the teaching of science to promote the Scientific and Technological Literacy (STL). Through this perspective, we developed a STS thematic approach in the discipline of Chemistry in a secondary school classroom of a public school in the metropolitan region of Curitiba-Brazil. The didactic and pedagogic intervention has been built from a series of STL parameters linked to the Indoor Air Quality (IAQ) topic and with specific contents of the discipline. We adopted a qualitative research methodology, with an interpretative approach, and we analyzed the gathered data using the Discursive Textual Analysis based on the work of Moraes and Galiazzi (2007). Data analysis shows that the development of the proposed intervention helped the students to be aware of the links between the addressed knowledge and their life context, supporting the understanding of the scientific content explored. Furthermore, we observed an increased interest and participation of the students during classes, followed by reflections of the nature of science, technology, and the multiple relationships between the scientific and technological context and the social environment.

***Keywords:*** STS; STL; Secondary School; Chemistry teaching; Indoor Air Quality.

## Introduction

In the educational context, several studies search for alternatives to overcome the contradictions resulting from an abstract, decontextualized, and teacher-centered approach in science education (CARLETTO; PINHEIRO, 2010). Nonetheless, pedagogic practices exclusively based on repetition and memorization of a considerable amount of information are still common in most Brazilian schools, finding its value applicable only to examinations and specific tests. These practices often teach a series of disposable knowledge with no actual meaning in the outside world (eventually, they are meaningless even inside the school environment).

In order to surpass these teaching models, authors like Auler and Delizoicov (2001), Aikenhead (2003), and Milaré, Richetti and Pinho Alves (2009), among others, discuss the need of new perspectives and approaches to overpass the mere transmission of scientific knowledge disconnected from the student's reality, and of alternatives to promote a scientific and technologic literacy (STL). In this way, students would be educated to citizenship duties and responsibilities in a social environment that is increasingly connected to scientific and technological advancements.

As part of such debates, the science teaching literature suggests different methodological approaches to contemplate an education that is capable of facing the challenges of a STL process. Among these approaches, the ramifications of a movement originated in the mid 1900s stand out: the Science, Technology and Society (STS) Movement.

STS focus approaches[1] allow a more realistic interpretation of the influences the techno sciences have over the social framework when introduced in the scholar environment, as they emphasize the relationships between the sociocultural context of those involved in the teaching and learning processes and the scientific and technological concepts, making possible the insurgence of debates about the nature of science, the nature of technology, and its social unfolding and inter-relationships (SANTOS; MORTIMER, 2002; SANTOS; SCHNETZLER, 2003; STRIEDER, 2012).

In respect to its implementation, several educational proposals advocate for a new organization of the schools' syllabus based on specific topics (SANTOS; MORTIMER, 2002; SANTOS; SCHNETZLER, 2003; STRIEDER; KAWAMURA, 2009; BOCHECO, 2011). These proposals are backed up by official documents, especially those regarding to curricula selection and contextualization and participation of teachers in the elaboration of the curriculum, in the definition of methodologies and in teaching strategies (HUNSCHE; DELIZOICOV, 2011).

Considering the need for reflections supported by classroom concrete experiences, in this paper we intend to collaborate to the analysis of the contributions resulting from the insertion of a thematic STS focus in the chemistry subject thought to a second year of secondary school class from a public school in the metropolitan region of Curitiba – Brazil (OLIVEIRA; GUIMARÃES; LORENZETTI, 2015).

We selected the Indoor Air Quality (IAQ) as the topic to guide our proposal. Its study involves the analysis and the care of air quality in the interior of residences, buildings, schools, factories, offices, or any other places, especially where it relates to its occupant's health and comfort. Our choice was justified for IAQ has a potential to play the role of an articulator element in STS debates, for its comprehensiveness and social significance, in a scenario where the provision of healthy indoor air is recognized to

1 We used the expression "STS focus" to describe the STS Movement developments in the educational scenario for it is commonly adopted in the science teaching literature. The expression "STS Movement" is used to designate STS debates in a broader social context. Finally, the term "STS approach" is employed for the didactic-pedagogic proposals that contemplate the relationships.

be a fundamental human right per the World Health Organization (WHO), therefore recognized as a determinant of health and well-being of all (WHO, 2009).

In order to make relevant important aspects of our proposal explicit, initially we discuss the theoretical presuppositions that support its structure to allow reflections about the application of STS approaches in the secondary school, particularly in chemistry teaching. Afterwards, we analyze the topic IAQ and emphasize its potential as STS relationship articulator topic through a series of STL parameters. Finally, we present the research methodological pathway and the positive results obtained through this intervention.

## Science, technology, society, and chemistry teaching

Chemistry, a historically developed science, studies the composition of matter, its structure and changes, being part of scientific and technological development of humanity. When transposed to the scholar context, this science has potential to extend the understanding of nature and technological processes that permeate society, allowing a new interpretation of the world and an increased opportunity for the practice of citizenship duties.

Nonetheless, it is a common find that this knowledge is reduced to resolving and repetition of exercises where the student learn a specific concept with the sole aim to solve new activities the teacher has proposed. This strictly conceptual manner to dealing with learning not only results in lack of interest about science subjects (PRAIA; GIL-PÉREZ; VILCHES, 2007) but also constitute a barrier to students to establish a relationship between the disciplinary concepts and their everyday lives (BOCHECO, 2011).

Intending to overcome the distancing and conceptual abstraction that traditionally characterize the chemistry teaching process, we defend the need to approach the specific subject contents in a way which creates an association of these contents to an applicable context emphasizing the social function of every topic, closing the existing gap that makes these topics away from the student's reality. Instead of diminish the importance of the contents, such an approach aggregate new meanings to chemical contents and open opportunities for new understandings about its importance in a society influenced by scientific and technological relationships and inter-relationships.

This perspective is present in official documents and the National Curriculum Guidelines explicitly assume that the chemistry subject knowledge is fundamental to provide the student appropriate instruments needed in a decision-making process, serving as a cultural tool for the interpretation and transformation of the reality, promoting conditions for the fulfillment of the citizenship role. According to these documents:

> The Chemistry learning process undertaken by secondary school students implies they understand the chemical transformations in the physical world in a comprehensive and integrated way so that they

> can, therefore, make judgments about information received from cultural traditions, media, and from the school, and make autonomous decisions as individuals and citizens based on fundamental principles. This learning process should allow the student an understanding of both, the chemistry processes per and the development of a scientific knowledge that comes close together with its technological applications and its environmental, social, political, and economical implications (BRAZIL, 1998, p. 30).

We believe that to make these objectives possible it is crucial to promote students' scientific and technological literacy through a solid scientific knowledge base, as well as to promote the importance of continuing learning, questioning, and taking positions concerning social challenges.

This aim goes in line with the STS-oriented education intentions since the approaches that contemplate these interactions support both the problematization of concepts and students to build knowledge, abilities, and the necessary values to make responsible decisions about questions in science and technology in the society so that they may play a role in solving such questions (SANTOS; MORTIMER, 2002).

## The STS focus in the research context

Discussions about the relationship between science and technology with society have been developed for a while. Several publications (some emphasizing different aspects of this interplay) describe the genesis of the reflections about the STS interactions (LINSINGEN, 2007; BOCHECO, 2011; STRIEDER, 2012).

Its origin goes back to the mid-twentieth century with the unfolding of several academic and social movements in the Northern Hemisphere reflecting the dissatisfaction towards science and technology traditional concept, the political and economic problems related to scientific and technological development, and the environmental degradation (STRIEDER, 2012). It was then that, under different perspectives, discussions about the interrelation of science and technology with society started gaining shape.

These initiatives had repercussion in the educational field and, according to Pinheiro, Silveira and Bazzo (2007), the STS studies reflect that period of time and are used as a base for building curricula, especially those of scientific subjects, prioritizing the scientific and technological literacy interconnected with the social context.

Strieder and Kawamura (2009) state that despite the vast diversity of positioning and the intrinsic complexity of the involved questions, in general the proposals involving STS share two common characteristics: (i) the search for a teaching model that can contribute for changing the understanding of the role science and technology play in society and vice-versa and (ii) the development of social learning capable of providing opportunity for citizens to use the knowledge acquired in school for critical reasoning and decision about questions related to the scientific and technological context.

Thus, in order to articulate a teaching proposal to a STS approach independent of the theoretical reference adopted, it is important to emphasize the social dimension of the scientific and technological knowledge and its transforming potential. Fundamentally, it refers to a perspective's change in relation to the knowledge acquired in school. Teaching practice needs to be a mediator among the discussion about this knowledge to gather together the subject contents and the reality that students experience, deconstructing the idea that such knowledge is useless outside the school environment.

In this context, there is reasonable consensus in the science teaching literature about the STS focus being structured in a new topic-based curricular organization (BOCHECO, 2011). Santos and Schnetzler (2003) outline this tendency in a literature review on teaching proposals based on STS approaches. They show that all included papers recommend its development having the topics as starting point as they "have highlighted the interrelationships of the STS aspects and have favored appropriate conditions for the development of students' decision-making attitudes" (SANTOS; SCHNETZLER, 2003, p. 74).

In this way, Delizoicov, Angotti, and Pernambuco (2002) recommend that subject contents selection be defined according to the topics, subjecting the choice of scientific concepts to the understanding of the topic. The authors also state that the selection of topics is done according to their relevance and importance in students' social context and, from their analysis, students either problematize or question their own knowledge until they feel the need to have scientific knowledge to explain the situations presented to them.

The same authors also suggest that the working process with the topics should be structured in a three-step sequence, called Three Pedagogical Moments (3PM). The 3PM propose the establishment of a dynamic dialogue between teacher and students, and the sequence is comprised by three steps: *initial problematization*, *knowledge organization*, and *knowledge application*. In the first step, students are encouraged to think and problematize about the presented situations, trying discuss the topic and check over their previous knowledge. This is followed by the knowledge organization, when the teacher develops the necessary knowledge for the understanding of the central topic and the questions that have been raised in the initial problematization. The knowledge application is performed to deepen the initial questioning students have suggested as well as to debate other situations related to the topic but that have not been approached previously.

From these considerations and reflections about the importance to emphasize the STS interactions in chemistry teaching that goes beyond the scholar boundaries to allow the development of decision-making capacities in issues that involve relationships between science, technology, and society, we acknowledge that the STS focus thematic proposals should be organized in a way to make socially relevant topics and teaching strategies that welcome the active participation of students its central point.

Thus, to build our proposal we opted to use the 3PM as a framework of our classroom work giving its potential to raise discussion, reflection and dialogue between tutor and pupils. Regarding the topic selection, we adopted a thematic broad enough to permit its application to different contexts and that, despite not being associated to a specific community, still presents a vast social impact. Hence, we decided to go ahead with the *Indoor Air Quality* study due to its importance for increasing the level of quality of life and its potential for serving as an articulating element among the chemistry subject contents and STS discussions.

Intending to bring to light the social relevance of the chosen topic and its correlation with chemistry teaching, next we discuss the IAQ highlighting that, in spite of its comprehensiveness, there are little research in the national literature about this issue, especially in the educational area. This justifies the fact that most references used to personalize the topic are international sources and most of them are related to health, engineering, architecture, and similar areas.

## The Indoor Air Quality

To increase the quality of life of a population, it is imperative an increased concern about the quality of the air we breathe and, initially, our biggest concern lies in the exterior air quality. Yet, nowadays people spend most of their time inside buildings or vehicles of any type and, contrary to prior belief, there are high levels of pollutants specific to these places and the quality of life ends up conditioned by the limitations these areas may present (VERDELHOS, 2011).

IAQ is regarded as one of the main public health environmental risk and, according to the WHO, interior air pollution is the eighth most important risk factor, responsible for 2.7% of the world's disease (WHO, 2009). Therefore, it is an essential determinant of health and wellbeing. Its thematic relevance is further emphasized as statistical measurements demonstrate that we spend around 80% to 90% of our time inside closed places (ASHMORE; DIMITROULOPOULOU, 2009).

Even though there have been large advancements in the level of information gathered around IAQ in the last years, there is still a lack of sensitization and information about this topic, particularly among those who occupy such environments. Interior air is considered a result of the interior climate, being solely related with thermic comfort aspects, even though the United States Environmental Protection Agency (EPA) have demonstrated that air pollutant levels inside buildings can be two to five times – occasionally more than 100 times – higher in comparison to exterior air (SANTOS, 2010).

IAQ control inside buildings is unquestionably a public health matter that needs a solution to benefit their occupants (VERDELHOS, 2011). Taking into consideration the fact that consumer spending habits and entertainment are tightly related with closed places, which are commonly subject to interior use of air conditioning, air purifier, or central heating systems, such as shopping centers, cinemas, restaurants, and nightclubs, the situation become even more serious.

Along these lines, the need for discussions about IAQ in the educational context is of great social relevance due to its public health importance and its potential as a tool for democratization of scientific and technological concepts when articulated with a STS approach.

## IAQ, the study of gases, and chemical kinetics

For the construction and development of a thematic STS proposal, it is necessary to consider the intrinsic difficulties related to the STS triad and its transposition to the educational context. Any discussion of this nature involves many variables that could have different meanings and interpretations.

Having said that, we sought to build a STS focus proposal that could boost students' scientific and technological literacy, in a way to avoid both the sole development of scientific concepts and the sole discussions about social issues, and that would consider all the STS triad elements and its ramifications.

Initially, we selected the subject's specific contents that had the highest potential to be used as a thematic articulator. The chosen contents were the *study of gases* and *chemical kinetics*. The choice was based on the close link between the topics and the thematic since most substances responsible for indoor air pollution exist in the gaseous state and their transformations involve chemical kinetic mechanisms.

In a subsequent step, we started working in a process to gather provisions to boost the discussions associated to the practical, political, ethical, and cultural aspects related to the STS interactions. To do this, we structured the didactic proposal from a series of parameters suggested by Bocheco (2011), which aim to correlate the STS theoretical assumptions with four scientific literacy and three technological literacy categories[2].

The four scientific literacy parameters considered in the elaboration of the proposal were: *practical scientific literacy, civic scientific literacy, cultural scientific literacy,* and *professional scientific literacy*. The first parameter consists of approaching the scientific knowledge to understand natural phenomena, processes, and artifacts present in day-to-day life; the second intends to stimulate debates about the social implications of science; the third allows discussions about science nature, history, and philosophy; and the last one targets on the stimulation of students' interest in the scientific or technological area through more complexes scientific concepts with little applicability to daily life (BOCHECO, 2011).

We used three parameters with respect to the technological literacy: *practical technological literacy, civic technological literacy,* and *cultural technological literacy*. The first aims to allow students to understand the characteristics and symbols in the technologic artifacts; the second debates the implications of technology in society; and the last one proposes a discussion about the nature of the technology and its relationship with science and society (BOCHECO, 2011).

2 Bocheco (2011) proposed STL parameters that have clearly been inspired on the levels of scientific literacy (practical, civic, and cultural) proposed by Shen (1975) and on the many subsequent interpretations of these.

Table 1. summarizes how the topics discussed in the classroom were related to the STS parameters during the didactic-pedagogical insertion.

Table 1. STL parameters and IAQ thematic

| Parameters | Topics for approaches related to the study of gases and chemical kinetics through the IAQ topic |
|---|---|
| Potential for Practical Scientific Literacy | Understanding of gases' properties and of the main factors that alter the reactions' speed. |
| | Recognizing the commonly found pollutants in indoor environments and its emission sources. |
| | Understanding the parameters of indoor air quality set by the present legislation. |
| Potential for Civic Scientific Literacy | Discussion of attitudes and alternatives to avoid or minimize the indoor air pollution damaging effects. |
| | Reflection on how indoor pollution-related pathologies interfere in people's quality of life. |
| Potential for Cultural Scientific Literacy | Analysis of the scientific model concept and the scientific theories limitations to characterize science as a human activity, transitory, and subject to different influences in its construction and development processes. |
| Potential for Professional Scientific Literacy | Understanding the catalytic converter working principle and its application in various industrial processes. |
| Potential for Practical Technological Literacy | Understanding the symbols and functionalities of the compact air purifiers. |
| Potential for Civic Technological Literacy | Establishment of criteria for the acquisition of air conditioning or air purifier equipment. |
| Potential for Cultural Technological Literacy | Refection about the nature of technology and how it interferes in our perception and interaction with the reality. |
| | Discussion about neutrality-intentionality and autonomy-control technological activities relationships. |

Source: The authors, 2015.

## Methodological and analytical option

The sample was a single second year of the secondary school class, comprised of 20 students (16-20 years old). As the school curricular organization is planned once every trimester, the proposed activities were performed in the last semester of 2013 during 14 50-minute lectures developed in seven weeks.

The lectures were organized according to the 3PM proposals: initial problematization, knowledge organization, and knowledge application. We prioritized activities that would encourage the participation and critical thinking of the students, such as group discussions, videos, experiments, group work, scientific journal papers, among others.

As we opted for an interpretive qualitative research with participant observation (MOREIRA; CALEFFE, 2006), we selected specific instruments to constitute data, which were the diaries produced by both the students and the teacher, and the questionnaires that were applied at the end of the process.

For writing the diaries, each of the 14 lectures was laid out by one of the students. The diary that has been completed in the one week was handed to the next student in the subsequent week. The students completed the diary using a narrative text in a way to present their impressions about the observed lecture and registering as many information as possible (methodology applied, external and internal interferences, time, content, their own and the colleagues' impressions, etc.). 254 diaries were obtained at the end of the proposal development, corresponding to approximately 18 diaries per class. Each diary was given a code (D001 to D254) maintaining the respondent's confidentiality.

At the end of the proposed didactic activities two opened-question questionnaires were applied. The first, called final questionnaire (QF01 to QF20), aimed to analyze the students' reaction level towards the contents related to the subject, topic, and articulation with STL parameters. The second was an evaluative questionnaire (QA01 to QA20) to capture the impressions students had about the proposal development and their participation in classroom discussions.

The Discursive Textual Analysis (DTA) (MORAES; GALIAZZI, 2007) was used to analyze collected data. We chose this technique as it combines rigorous analysis and synthesis, allowing the reconstruction of verbatim quotes of those involved in the research and the expansion of their meaning.

In DTA, the set of elements used is designated the research *corpus*. According to Moraes and Galiazzi (2007) these elements represent the research information and carry accounts that the researcher needs to describe and interpret discourses in order to set up meanings for the investigated phenomena. The research *corpus* is shown in Table 2.

Table 2. The research *Corpus*

| ***Corpus*** | **Research subjects** |
|---|---|
| 254 Diaries<br>20 Final questionnaires<br>20 Evaluative questionnaires | 20 secondary school students |

Source: The authors, 2015.

Data were analyzed after the definition of the research *corpus*. The analysis was carried out through common aspects detected in the documents or in the emerging divergent positions observed. Then, through these withdrawn elements that described the participants' perceptions, a series of analytical categories was produced.

As Moraes and Galiazzi (2007) stated, the categories elaboration process can start from two opposite points. One of them has objective and deductive nature and results in categories determined *a priori*, while the other is subjective and inductive, generating emergent categories.

For this research, the *a priori* formulation of defined categories originated from the theoretical referential used in the proposal construction and lecture development. The STL parameters described previously have been naturally constructed in pre-established analytical categories. Thus, based on this inference and supported by the DTA methodology, we generated seven *a priori* analytical categories: *Practical Scientific Literacy, Civic Scientific Literacy, Cultural Scientific Literacy, Professional Scientific Literacy, Practical Technological Literacy, Civic Technological Literacy,* and *Cultural Technological Literacy*.

As outlined by Moraes and Galiazzi (2007), a theoretical referential assists the construction of *a priori* categories and, on the other hand, it can also hinder the rise or identification of new categories for it makes the researcher conditioned to only see meanings that conform with categories that have been already determined. Likewise, as we analyzed the data set constructed during the investigation, we attempted to break the link we had with parameters that have been guiding our proposal and to search for new understandings reconstructed on the student's narratives.

In the process of establishing relationships and bringing together similar elements, we identified accounts related to the dynamic of the classes, the importance of experimentation, and the relationship between recording and learning in chemistry classes. All this information emerged from multiple voices in the analyzed texts and originated a new emergent category, formulated *a posteriori* and denominated *Didactic Strategies*.

## Results and reflections

When we incorporated the STS focus articulated to the STL perspective in the chemistry teaching context, we aimed to contribute to the development of an educational ground needed for the understanding of the subject's approached concepts as well as for training citizens capable of act according to scientific and technological perspectives of the contemporary society.

To verify to what extent this objective was reached, the information gathered through the narratives/accounts, questionnaires, and student's activities were organized in a series of categories, according to which we sought to produce new understandings. Table 3 shows the number of narratives identified in each of the established analytical categories.

Table 3. Analytical categories and the total of narratives

| Analytical categories | Total of narratives |
|---|---|
| Practical Scientific Literacy | 28 |
| Civic Scientific Literacy | 09 |
| Cultural Scientific Literacy | 30 |
| Professional Scientific Literacy | 01 |
| Practical Technological Literacy | 14 |
| Civic Technological Literacy | 15 |
| Cultural Technological Literacy | 20 |
| Didactic Strategies | 51 |

Source: The authors, 2015.

Table 3 shows that most narratives were classified in the emergent category *Didactic Strategies*. The numbers of those related to *Practical Scientific Literacy* and to the two categories of cultural literacy were also significant. On the other hand, only one text was identified in the *Professional Scientific Literacy* category.

Given the thematic specificities, the contents approached, and the dynamic applied in lessons, it is natural that some aspects related to specific categories were more frequently observed than others. Notwithstanding, despite the categories have their own meaning, the development of each of them have a direct impact on that of the others. It is the set of categories that permits the integration of debates about science, technology, and its social unfolding. This integration not only values each of the elements and emphasizes its intimately connected relationships but also highlights the multiple dimensions of the STS-oriented teaching.

Thus, before starting the discussion of the results, we would like to underline that, despite we have analyzed the objectives referred to each category separately, they are related to each other and, as a set, reflect the intentions of the proposal.

## (i) Practical scientific literacy

The practical scientific literacy relates with the capacity the students have of recognizing new meanings and utilities for the concepts discussed in chemistry classes. We sought to identify clues of the appropriation of knowledge that, associated with scientific contents and scientific language, would allow the students to understand phenomena and processes present in their daily lives. The category encompasses understandings that need to be discussed not only under the scientific knowledge perspective, but also under its usual implications. So, the practical scientific literacy manifests through the application of the studied knowledge in meaningful situations the students live.

The first clue found in the students' narratives associated to the potential of practical scientific literacy is related to their understandings about the relationship between the thematic and the daily life. Before the starting of class discussions, most the pupils did not have any concrete information about the IAQ and, during the proposal development, it was possible to notice the appropriation of knowledge about the theme through their level of conversation during the classes and further demonstration in the answers of the questionnaires that were applied at the end of the teaching. Some verbatim quotes from the students' narratives at the end of the didactic proposal are:

> Yes, it is very important to know the condition of the air quality in closed places, because we can then know how to take care of our health and how to try to purify the air from where we live. [...] we learned many things with this theme and we can appreciate this theme outside the school for our benefit, since studying this theme make possible to learn how to prevent diseases and harms that surround us. (QF03)

> Yes, it is very important to study about this, because we can find out how to improve our health, how everything works since air pollution to ways to make the environment quality improved for us to live better. (QF04)

These quotes indicate that the students understood the importance of the topic, underlying that this process was not confined to the acquisition of information. As the students underscored, the relevance of the IAQ lies on "find out how to improve our health, how everything works, since air pollution to ways to make the environment quality improved for us to live better" (QF04). Analyzing these quotes, it is evident that the domain of topics goes beyond the simple description of the characteristics of indoor air pollution and involves the understanding of what the agents, equipment, and care are, and the necessary actions for improvement of indoor air quality.

While at the start of the discussions the students just showed surprise and concern about the impacts of IAQ, at the end of the teaching process, when they had been stimulated to reflect about the topic, besides confirming their previous concern, they put special emphasis on the need to act to prevent and fight against indoor pollution. These results indicate that it is possible that the initial curiosity in relation to a topic that they did not have much information about was used as an instrument of mobilization for the understanding and awareness of its relevance, showing the need to know more about something that directly affects their quality of life.

Another face of the practical scientific literacy process consists of correlation between scientific contents and situations students have lived in their daily lives.

Chemistry, as other scientific subjects, has a vast potential to present explanations to several natural phenomena and daily experiences, allowing the interpretation of the world from the perspective of scientific knowledge. As the utility of this knowledge on the outside world is emphasized, the teacher presents other meanings to the subject contents, providing new understandings about the importance they have. In relation to these aspects, the following verbatim quotes are relevant:

> In this lesson, it was taught to us through experiments that the chemical reactions (or at least part of them) can be controlled. And we do this several times in our daily lives without realizing it. When using a pressure pan to cook, for instance, there is an influence that makes the beans, or whatever it is inside it, to cook quicker. (D176)

> I particularly enjoyed the class and learned much more. For instance, I did not know that the potatoes' enzymes could speed a chemical reaction. I've now learnt with this experience and really enjoyed it. (D180)

The quotes point that the pupils could associate various specific concepts of the subject, such as the influence of the temperature, pressure, contact area, and catalysts (enzymes) in chemical reactions, with situations presented in their lives. This association is fundamental for the students to realize the importance of Chemistry in their lives outside the school and draw attention to the need that teaching should also present an immediate significance to the students and not only in a posterior moment.

It is worth to underline that we are not defending the mere utilitarian and immediatist teaching that is only concerned with the application of the knowledge acquired in school. On the contrary, we pursue to give a meaning to what is taught and to defend a teaching model that shows itself capable of dealing with concrete problems. This is one of the most relevant characteristics of the scientific literacy process' practical dimension: its potential to correlate the scientific knowledge with the reality the students live in, leaving behind the false impression that the acquired knowledge ends in itself.

In the student's narrative, the perception of new possibilities for the use of the subject's contents is also recurrent. This have modified the way they face chemistry and the other scientific subjects, as shown in the following quotations:

> I see differently now, <u>I see that scientific subjects are not just math calculations</u>, they are things we see or do in the day-to-day life and that we don't know are considered science, like the chemical reactions. (QF01)

> During all the classes, <u>it was possible to learn a bit more about the different places we can find chemistry in our routine</u>. All the classes <u>helped me to see how scientific subjects can support us to have better concept of what is around us</u> and to know how certain things sometimes seem to have no importance to those who doesn't pay attention but can make all the difference in certain occasions. (QF03)

> [...] now I think <u>that Chemistry is not just a subject studied in the school and needed for the examinations</u>, but it is something that makes part of our daily lives. Many things I have learnt I use in my daily life now. (QF10, our emphases).

It could be noted that the daily applications of chemical knowledge helped the students to perceive the subject as something useful outside the school environment and laboratories. In this way, besides contributing to the development of scientific basic knowledge necessary for the interpretation of the world they live in, the practical dimension used in the scientific literacy process in chemistry classes also contributes to change the image students have about the subject.

This aspect (perceptions about science and science activities) is discussed during the analysis of the category related to the cultural scientific literacy. Yet, we find pertinent to present these narratives here for they have direct relation to scientific knowledge practical implications and, in doing so, we emphasize again that none of the STL categories are disconnect from each other.

### (ii) Civic scientific literacy

Civic scientific literacy is associated to the development of the students' critical positioning for decision-making process regarding problems that directly affect their lives. The fact that the pupil dominates the information given to him is not enough for his growth as a responsible and active citizen. It is also necessary to analyze and discuss problems through a questioning attitude, considering the divergent opinions and recognizing the need of decision-making skills.

In the scientific literacy process the civic dimension put emphasis on the principles that involve necessary actions for that the citizen can take well-grounded decisions and can actively participate in the choice of the paths given to scientific technological development. According to Bocheco (2011), to develop this capacity it is necessary that the students be stimulated to deal with decisions that require negotiations and choices, especially regarding to health care, environment, and wellbeing.

In this way, to identify evidence of civic scientific literacy, we used the students' narratives that have emphasized the attitudes and alternatives to avoid or minimize indoor air pollution damaging effects as analytical objects. Taking a closer examination of these elements, we noticed that the students were able to question the information given, to analyze alternatives, and to position themselves in front of the contradictions and challenges proposed by the IAQ thematic discussion. We understood that this positioning could occur in two ways: first, taking into consideration the students' perceptions in relation to a given situation, and second, considering the possibility of concrete actions to face the problem.

Regarding the students' perception towards the problematic involved, some students mentioned that the teaching approach contributed so that they could have an opinion about the situation, as evidenced by the following excerpts:

> A video showing the inside of an air conditioning was played, a lot of dust, dirty, rests of dead rats, mold, etc. was found with the camera. And in the video, it was said that the poorly constructed, poorly illuminated, and poorly ventilated buildings can, with time, acquire the sick building syndrome, better known as SBS. […] The video showed that there is a disease called Legionella, which can even lead a person to death, all because of a lack of care and constant maintenance of an air conditioning. In 1970, these deadly bacteria originated 182 cases of pneumonia and 30 death people. All because of lack of care in a hotel in Philadelphia. That is why the constant maintenance and the displaying of when it was done and if everything is all right is important, because the lack of care of one person can take many people's lives to pay for it. (D113)

> During the class, we discussed about how harmful an air conditioning can be for our health, as it can lead us to death. Sick buildings are a problem and we should not stay in these places and, if that is the case, we should get information about its maintenance. (D118)

One characteristic that can be highlighted in the above excerpts is that all students that showed their positioning pointed the topic's relevance and the need of care of building's indoor air, especially in those places having air conditioning. Also underscored were concern with regularity of maintenance, the communication of information about the air conditioning's air quality, and the sick building syndrome[3]. This indicates that students associated the importance IAQ has to their quality of life and reinforces the understanding that this topic takes part of their sociocultural context.

Other pupils specifically argued about the need of decision-making attitudes towards IAQ-associated problems, as shown in the following quotes:

> The air conditioning should be cleaned weekly, because the dirt can cause disease in people. In shopping centers the danger is always higher because we never know if it is clean or not. […] I cannot put in words what I've understood, but now I know I can sue the building if I get ill in that place. (D108)

> [...] to know how to prevent yourself you have to know what happens and then take prevention. […] I've already changed many habits to increase the indoor air quality. (QF15)

The excerpts indicate that the concern about IAQ advanced beyond the acquisition of information or the implications of their knowledge, and show the need for actions to face the problem. These actions can involve habit changes or direct attitudes, as those demonstrated by the students. In any way, the perception of this need indicates that the school knowledge has become an intermediate and not the end anymore, as a necessary instrument to make judgments, take decisions and actions.

The indications of the civic scientific literacy (either through reflections in relation to the IAQ-associated problematic or the possibility of specific actions) reinforce the need of teaching practices that not only seek to contextualize the knowledge approached in class, but also to favor conditions for the students to be conscious about their role in the social context they are immersed in.

### (iii) Cultural scientific literacy

In the category related to the cultural scientific literacy, we analyzed if the development of the didactic process disturbed the students' conceptions about the nature of the scientific knowledge, in a way to infer whether the proposal contributed for the perception of science as an essentially human activity in which its political, social, and

3 According to Strauz (2011), the term Sick Building Syndrome (SBS) is used to describe situations where at least 20% of the occupiers experience acute effects in their health or comfort that seem related to staying inside them and not as a specific disease or an identified cause.

economical implications have influence over its construction process and development.

The first aspect analyzed refers to the models and scientific theories formulation processes. By seeking for elements that could characterize the scientific activity in students' response, we aimed at investigating if they have understood how such processes would occur. Thus, we investigate which path should be taken for the formulation of a model, a law, or scientific theory, as well as the limitations these representations present. In regards to these aspects, the excerptions ahead are highlighted:

> [...] a scientific model is not an exact model of the things, but has similar characteristics and <u>can always be changing in some detail</u>. It is used to explain or represent some theory. (D076)
>
> Ideal gases are models, representations of the gases that exist in the real world. As it was seen in the lecture about models, <u>it is practically impossible to establish a model that is perfectly consistent with the reality</u>. Models like the ones of ideal gases are perfectly measurable. How it is possible to measure, to weight a real gas? That is why the model exists. Gases behave in different ways in certain temperatures. However, there are cases where the real gases behave like described in the model. (D106, our emphases)

These quotes indicate that the classes' discussions supported the students to perceive that the scientific models  are not a copy of the reality, but are useful representations for supporting the understanding of certain phenomena or the formulation of theories. These representations not frequently present direct correlation with observable facts in the natural world or accurately express some phenomenon or event. This observation is important for the students realize some intrinsic limitations of the nature of the scientific work.

Another important point to be considered is about the models' tentativeness and validity, as above underlined in diary D076 and expressed by other students:

> A scientific theory is never finished and the so called 'scientific truths' or 'to be scientifically proved' is something that is accepted based in current researches. This means that there is no way for the researches to get a concrete answer. They have no means to involve all people in the world in a test to know if certain product is harmful for someone. (D082)
>
> In general, a scientific theory is based on information and observations done by many other scientists who reached the same conclusion several times. But not even the fact of have been tested several times by several different scientists makes the true completely unquestionable for there could always be contradictions. (D085)

The verbatim quotes show that the students have started to question science's traditional conception that characterizes it as a definite, reliable, and objective process.

According to Gil-Pérez et al. (2001), the envisioning of a rigid science, as a result of an infallible scientific method in which the set of steps to be mechanically followed, a quantitative treatment, and a rigorous control avoid the ambiguity, distort the uncertain character of the scientific theories and display itself as a deformed conception of science. It is not about ignoring norms, habits, and science techniques, but about understanding that is not the mere observance of a set of rules that fundaments the scientific activity. This set of rules displays itself as a series of socially accepted recommendations by the scientific community, which by its own, does not imply any certainty.

Therefore, we can consider that the didactical proposal contributed to show that the scientific reasoning modifies with time, evidencing that the models and scientific theories are not definitive constructions, but subject to constant revision. To assume the tentativeness and the uncertainties, to value attempts, and to understand the scientific activity as a process in permanent construction also contribute to broaden students' views on science, to allow them to evaluate specialists' controversial positioning, and to accept different alternatives to solve a given problem (SOLOMON, 1998).

Students' texts also showed information about their views about scientists' image and external influences in the construction of scientific knowledge.

About these aspects, a quick Internet search in enough to notice how scientists and the research activity are socially portrayed. In general, the scientist is a male, lone, sloppy, and genius individual. This eccentric individual interacts only with his own work and has a laboratory as the main reference of work (GIORDAN; KOSMINSKY, 2002). From this caricature disseminated in the media and socially accepted it derives a false impression that science is an activity for some few chosen individuals, a privileged minority.

According to Gil-Pérez et al. (2001) the characterization of science as an individualist, elitist, and predominantly male activity transmits negatives expectations to students, discouraging their interest for science. These authors also argue that the scientists' image as human beings disconnected from the reality, free from the need to make choices, and being above good and evil reinforces a socially neutral science conception. It follows that science, technology, and society are autonomous and distinct entities, without connections, and which do not affect each other. The following excerpts show these aspects:

> We cannot stop believing in science, but even if we believe we cannot 'blindly believe' because nothing related to science is totally reliable, proved. Science gets as closer to the truth as possible. The scientist is a normal citizen as we are, the difference is that he studied science, did experiments, research. He can be supported by other people and his decisions can be influenced by them. (D086)

> I don't think science is neutral, because as some people use it appropriately, other use it for doing wrong things and end up damaging other people and themselves. […] I've always thought that science

> explained the truth, the fact of something. Every time I've heard people saying in the television that some research has been done and that something was bad or good for people I didn't question. I thought that everything was truth and that 'if the scientists said I can't do anything else'. But no, with this semester's lectures I've learnt that not all research is truth and that if we think that it is wrong, we should raise questions, confront it, say what we think, and don't accept everything submissively. (QF12)

The verbatim quotes show that the students started to notice scientists as ordinary people who, as any other professional, faces challenges, contradictions, and are under multiple influences in work. Even though the scientific activity has not been mentioned as a non-male work, and there were no recognition that men and women practice and do science in the same frequency and competence, we believe that our didactic unit could disturb some widespread concepts about the nature of science as we put in evidence the human and subjective character of the scientific work.

Finally, the last analyzed aspect in relation to cultural scientific literacy is associated with how students view science and scientific subjects .

Despite its importance in our society, scientific knowledge presented in schools neither reflect any of the science's aspects as a human enterprise nor nurture curiosity or student's interests. In a society in which information is easily accessible and in which it takes one single mouse click to uncover formulae, reactions and used of any chemical substance or published industrial process for instance, it is not possible to sustain any longer the argument that is necessary to go to school only to acquire knowledge.

This conjuncture implies a teaching model distant to the mere reproduction of knowledge and concerns about granting means for the students to perceive scientific knowledge as an important part of their lives. In other words, scientific knowledge not only needs to be faced for its daily utility or its specific codes and languages, but as part of the cultural diversity that characterizes the time we live in. We know that this process happens in both, formal and informal environments, spontaneously and continuously. Yet, we believe that it is the school role to support students to perceive science as one among other cultural practices socially legitimated.

Analysis of the students' questionnaires answers about these aspects at the end of the didactic unit presented significant excerpts:

> All classes helped me to see how scientific subjects can help us to have a better view of what is around us, and to know how certain things work, that sometimes it even looks like something without importance to someone who doesn't pay attention, but that can make all the difference in certain occasions. That is because, in a certain way, these classes make the students wiser and aware towards the study and helped us to pay more attention to the world we live in. (QF03)

> I've already thought science in general was fascinating, but the classes

> expanded my liking for it. In addition to reinforce, as always, that 'everything is chemistry'. However, the best thing is that I don't face science as 'pure calculations' anymore, but as something more than that. It involves not only the meanings and axioms, but also the use and interpretation of language and the world that surrounds us. (QF14)

In the answers, we notice that science and scientific subjects were no longer seen only as boring, complicated, and out of context subjects. The scientific activity has become a mean for the interpretation of the reality – of the "language and the world" (QF14) –, thus, consisting of a mechanism for personal enhancement that is within everyone's reach.

The admiration demonstrated in the students' texts can be seen as an additional step in a cultural scientific literacy process, in which despite the recognized limitations and contradictions in the constructions and development of scientific knowledge, science is still recognized as a necessary tool for the understanding of the world we live in.

### (iv) Professional scientific literacy

This category was built to analyze indications that the development of the didactic proposal has encouraged the students to work with science and related areas.

The professional dimension of a scientific literacy process aims to emphasize the economic importance of a given topic or accentuate aspects related to students' professional education. According to Milaré, Richetti, and Pinho Alves (2009), this dimension involves approaching more specific and complexes knowledge that are not easily applicable in a daily basis but that, on the other hand, are important in certain professional areas and are included in chemistry applied to the productive sector.

The analysis of the texts produced presented a single account that directly mention the interest in following a certain scientific career. According to the account:

> This part of calculations is the one that I like most, as I find it easy to calculate, especially when I can make them. I want to be an engineer or architect, for this are the things I have aptitude for and that I like too. (D095)

In the excerpt, the student intends to get involved in professional activities related to exact sciences (architecture or engineering) in a near future. She argues that have always had aptitude for calculation and shows that this characteristic made her become keen of scientific subjects.

Despite the analyzed data set has presented this single text associated to the professional scientific literacy category, we believe that the development of the didactic unit has provided support (directly or indirectly) to enhance a preexisting vocational characteristic.

## (v) Practical technological literacy

Practical technological literacy relates to capturing basic technological knowledge of immediate use. It involves the understanding of equipment functioning as well as the understanding of symbols and technological language in appliances routinely used. These abilities are fundamental for autonomy in the technological context and help to provide means for individuals to interact with these appliances.

We used this topic comprehensiveness to reflect with the students about the functionalities and the symbols associated to air conditioning and air purifying appliances. The excerpts bellow emphasize these aspects:

> Some vacuum cleaners use HEPA-type filters. This type is very good because it is projected to retain the particles that are harmful to health while brooms and dusters raise dust particles and disperse mite throughout the air. (D138)

> Yes, because from this we will know which electrical appliance is adequate for us and its functions. We learned how to understand its technical specifications, making its maintenance improved and safer. (QF06)

In their narratives, the students have highlighted some technical characteristics about the operation of appliances developed for air purification and air conditioning, like their uses, functions, and limitations. The lack of knowledge about the characteristics of certain appliances used daily besides preventing citizens to satisfactorily interact with these appliances, usually implies in its misuse and, eventually, puts the user at risk.

In this sense, we highlight the narratives about the terminology used in some vacuum cleaners' filters (HEPA). HEPA filters provide domestic cleaning and assist in indoor air purification, removing mites and microorganisms. This is a significant example that the understanding of technological language elements allows citizens to choose more appropriately, to optimize the use of the several technological resources available and, by recognizing the appliance's potentialities, to increase their quality of life.

## (vi) Civic technological literacy

While the category practical technological literacy aimed to verify if students were familiar with the technological artifacts' symbols and functionality routinely, the category civic technological literacy searches for indications of reflections about the appliances' real need and about the role everyone has as user and consumer of these technologies.

In this way, during the discussions we tried to assist the students in defining criteria for the acquisition of an air conditioning or air purifying, considering the cost-benefit relations involved. About these aspects, several of the students' narratives during the didactic unit are emphasized, of which we selected some to exemplify this aspect:

> What are the most effective ways to provide an improved indoor

> air quality? The answer is simple: the most effective way to solve this problem is reducing the source of pollution and using adequate ventilation. If everybody does this, the inside home air will get a lot better. Personally, I've really enjoyed the class and learnt that the best thing is to have adequate ventilation and decrease pollution. This favors our health more than buying indoor air purifying appliances. (D142)

> Yes, because now I can say to them that is not adequate to buy that appliance. That the most adequate is one that doesn't cause harm to our health and now I understand which one would be the best. And when I say something that I've learnt in the school my parents believe and try to follow. (QF02, our emphases)

We noticed that students bring out the need of criteria for the selection and acquisition of an air purifier or air conditioning. They indicate that despite most appliances have similar characteristics, what should be considered when buying them are the specific characteristics of each one.

The indications that the reflections helped the students to perceive their role as opinion shapers are also highlighted. Their deeper knowledge about the topic can (and should) influence the choices of people around them. For a technological education concerned with shaping responsible consumers, it is vital to know the characteristics, implications, dangers, and care needed for the acquisition or usage of a certain technological appliance. Far from instigate an anti-technological position and reinforcing only technologies' and associate appliances' negative characteristics, it is about to encourage students to adopt a critical attitude in relation to the need and the implications of the indiscriminate use of these appliances.

### (vii) Cultural technological literacy

Cultural technological literacy involves understanding what is technology, to perceive the technological activity as a result of a network of human relations, with their own motivations, influences, values, contradictions, and interests. Having said that, and supported by the set of proposed activities and on the debates in class, we tried to help the students to critically position themselves about the nature of technology and to perceive its strait relation with the social context in which they live in.

With this intention, initially we focused the analysis on identifying if there was a difference between the technological activity, the scientific activity, and the (mere) use or production of technological appliances in the students' narratives. We sought indicators that the technology has become a field of knowledge which is not just about the manufacture of appliances and that, despite its fertile and intrinsic relation, it is also not an applied science (in which both – science and technology – can take different pathways).

About these aspects, the following excerpts are significant:

> We've seen that technology is not just electrical appliances and that

> it's more present in our lives than we have imagined. Nowadays it's difficult to detach of the technological world. Technology is very good and important to our lives, because it facilitates our tasks and makes our lives easier. Several diseases and limitations are overcome and life extends through the technology. But at the same time, it brings some disadvantages like the controlling and manipulation of our lives. (D158)

> We are surrounded by technology all the time and in every way, and generally when there is no reflection about what is around us there is the tendency to stagnate. When we think critically we conclude that technology hugely influences our society and the reflection was put aside because of it. To avoid the dominance of what has been created over those who has created, it is necessary to be conscious of other technologies' purposes and the ways they influence our lives, as it had its own life. This reflection (it's uncertain) can help us to shed light over some conceptions, helping us to decide its pathways and to use technology according its objective: to make people's lives better. It depends of each one of us not to be negligent. […] We can define technology as everything that has been developed by human hands during history. To discuss technology is to discuss science, constructions, equipment, and its influences over society and the Earth. (QF14)

The descriptions indicate that students perceived that the objects themselves do not define technology; that these artifacts are just products of the technological activity, the result of a series of human and non-human actions (organizational, technical, social, and cultural aspects) that make possible the materialization and valuation of the objects (LINSINGEN, 2007).

Students also demonstrated an understanding that technology involves a set of specific and heterogeneous studies different from those associated with the scientific activity.

According to the classical view, it is the science's duty to provide theoretical basis for the technological construction. In this scheme, science has always anticipated technology. However, this disparity is far too abstract and there are several examples in the literature that demystifies this positioning, by recognizing that technology is also capable of creating science. Examples are the lenses technology, which had its origins before the optic science. Thus, Galileo did not know how the telescope, that allowed him to revolutionize astronomy, worked. In the same way, the steam engine that boosted the Industrial Revolution was created before the thermodynamic principles have been established (CASTELFRANCHI, 2008).

On the other hand, there are countless scientific theories that emerged irrespective of any technological findings. It has become essential to appreciate that despite the idea of hybridization of these fruitful areas of knowledge, this does not explain the complexities and specificities of each of these areas of human knowledge.

In the students' narratives, it is also distinguishable the concern in measure the broad scope of technology and how much it interferes in our lives. They argue that is difficult to disconnect the natural from the artificial world, that their frontiers are increasingly subtle and that "we are surrounded by technology all the time and in every way" (QF14).

This omnipresence awareness results in discomfort, mainly taking into consideration that the relationship is not frequently consensual. At the same time the students agree that technology makes our lives better and easier, they also demonstrate anxiety about the direction technological activity is taking, especially with the decision powder it has in this process. Technology growth speed and its influence over the most diverse aspects of humans life do not seem to allow a deep reflection of its implications.

It is evident, thus, that there is a growing need to introduce discussions about the human nature of the technological activities, seeking to overcome the "technological somnambulism" (WINNER, 1986) which characterizes the accommodated behavior most individuals present in front of technology and its by-products.

### (viii) Didactic strategies

As previously emphasized, the theoretical ground used in the construction and development of the didactic unit has naturally configured itself in a set of analytical categories defined *a priori.*

During the research *corpus*' analytical process, the reading and interpretation of the students' texts showed a series of common elements, constituting a new analytical category defined *a posteriori*. This emergent category relates to students' perceptions about the dynamic of the classes, their participation in the discussions, and their impressions about the lectures.

In this manner, the first highlighted aspect relates to the way classes were developed.

In general, chemical teaching in secondary schools faces resistance from students. According Mortimer and Machado (2011), this resistance derives from a teaching model that does not envisage the construction of knowledge and is based on memorization of formulas, tips, or simply on the application of knowledge that is not frequently used.

Even though the increasing specialization has put some chemical concepts away from general culture, its importance in people's life is undeniable. This occurs not only through its by-products, but also due to its presence on medicine innovations, improvement in productive techniques, increasing quality and life time, and the necessary knowledge to ground the debate and the participation in several social, environmental, and political questions. These and many other examples help to justify the need for practices that favor learning and stimulate interest in chemistry.

In this context, a new attitude to the subject contents intermediated by the STS focus provides opportunity to educate conscious and critical citizens and is one of the alternatives to recover students' interest for chemistry. Nonetheless, its effective implementation is not restricted to organization and contents changes only, but also involves the dynamic used in classes. Thus, we tried to give preference to activities and practices that would facilitate student's active participation during the classes and would value dialogue, investigative nature, and debate of ideas.

These aspects were noted in student's texts as shown in the following excepts:

> Today's class was very interesting, many people participated and gave their opinion, it was very good and participative. […] In my opinion, I liked the class because it was an iterative class and I got to know things I didn't know. (D0009)

> There has been loads of differences in relation to Chemistry classes from the beginning of the year. As the topic involved scientific theory, it looks easier to approach the topic in this way. Each of the classes started with an introduction followed by experiments, thoughts, writing, etc. This makes it clear, it doesn't look like a secondary school class – it's closer to an academic lecture. […] The classes have always been a preparation for the next and, after it has finished, the ideas were automatically organized in our mind. Instead of confronting ideas during the classes, a mutual iteration has occurred: the topics complemented each other, facilitating conclusions and settlement of ideas. The classes, exercises, and diaries were all pieces of a jigsaw that could only be assembled with all of them. (QA13)

Students have highlighted the difference between the classes developed during the didactic proposal and those traditional ones. They have accentuated that "many people gave their opinion" (D009), and that the proposed activities were like "pieces of a jigsaw that could only be assembled with all of them" (QA13), denoting the effect that the lectures were well articulated and more iterative, participative, and though-provoking.

We believe that the utilization of the 3PM (DELIZOICOV; ANGOTTI; PERNAMBUCO, 2002) provided support to give a new dynamic for the classes and added value to dialogue, evidencing to students the importance of their participation. They then started to lay their opinion without being afraid of criticisms or of being apprehensive about what the teacher or the colleagues would think about it.

Another aspect the students revealed relates to experiments done during the didactic and pedagogical incorporation process.

The search for methodologies that aid the teaching and learning development process in chemistry classes has increased in the last years, together with the consolidation of the chemistry education research in Brazil (SCHNETZLER; ARAGÃO, 1995). Among the possibilities presented in the literature, it is worth to point out the emphasis on experimental teaching, opposed to the traditional classes.

The experimentation has been extensively debated and has usually been pointed out as an important resource for the development of conceptual, procedural, and attitudinal knowledge (GALIAZZI et al., 2001). Santos and Schnetzler (1996) remind that, especially in chemistry teaching, the importance of experimentation lies in the characterization of its investigative role and its pedagogic function in helping students to understand chemical phenomena. Experimental activities convert themselves in instruments to support teaching and can instigate students curiosity in relation to topics approached during the class – having a motivational feature – and can contribute to the construction of scientific knowledge.

However, Francisco Júnior, Ferreira, and Hartwig (2008) argue that for experimental activities' pedagogic function could narrow the link between motivation and learning, the role of the educator is extremely important. This is so because, independently of the didactic resource or methodology employed, what makes a class more attractive to students is the teacher's planning. The teacher needs to consider the several possibilities of experimental work to focus his actions on those appearing to be as consistent as possible with the class' methodology, the approached topics, the issues to be discussed, the experiment's complexities, the students, the resources, the space, and the time available to perform them.

In this sense, we tried to perform experiments with low cost materials that could be developed in small groups and articulated through the 3PM dynamic. This option implied in an investigative experimental approach that aimed to overcome the common manipulation of materials or the exemplification of concepts and granted the discussion of experiments associated to its problematization.

The analysis of students' texts showed a series of accounts about their evaluations of the experiments performed. Some examples are:

> Prior to this experiment, there was another small experiment in which we should draw the spread of gas molecules around the room. We have concluded that learn with practical experience is much more beneficial. (D026)

> I found this lecture cool because I like things involving experiments, as we would never stop to reason about these things. When we have this type of lecture, we learn and discover new things. It makes me want to do more experiments so that we can discover more things that we would never discover. We can only learn this thing in these classes. The one of the balloon with the heated blanket was really nice. I enjoyed it. (D031)

When the students reported as conclusion that "learn with practical experience is much more beneficial" (D026) and that "it makes me want to do more experiments so that we can discover more things that we would never discover" (D031), stands out the learning mobilizing aspect achieved through experimental activities and its potential to excite students' curiosity towards scientific knowledge.

Finally, the last aspect concerned with the didactic strategies used in the proposal development that the students called attention to is related to the advantages of writing the diaries.

As we have stressed previously, during the classes in which the didactic unit was taking place, each student was responsible to write a narrative text about these classes. Besides representing a research data source, these diaries had a crucial role as learning facilitator tools in chemistry classes as they stimulated writing, memory, reflection, and provided means for students to express their opinion.

To Oliveira and Carvalho (2005), the discussion of ideas and text writing in science classes can be an important tool for gathering concepts, giving the unique potential of writing to organize and refine ideas about a specific topic. Concerning these aspects, we highlighted some quotes:

> It was a very good idea and it seems to have good results, since as we wrote what has happened in each class and what we have studied, we indirectly learned the topic and had a concrete opinion about what had been studied, being able to memorize the topic and the studied subject. Besides, the teacher could also evaluate how his classes were doing and how the students have learned, using it to improve his teaching methods. (QA02)

> In my opinion this helped a lot as we had something to be reminded and written at home. This helped because beside having to pay attention to write down about it later, we participated in activities to describe them. (QA05)

The fragments showed evidence of the importance of writing as a mechanism for recovering the subjects approached in class, since "as we wrote what has happened in each class and what we have studied, we indirectly learned the topic" and were "able to memorize the topic and the studied subject" (QA02). The students also argued that the responsibility to write about the classes implied in increased participation and attention, since "having to pay attention to write down about it later we participated in activities to describe them" (QA05).

According to Oliveira and Carvalho (2005), students value writing in science classes as it represents a moment in which they have the chance to express their understandings about the developed activities in an individual form. However, Oliveira and Carvalho (2005) also mention that it is important that the teacher builds an accurate looking at the students' writing material, allowing to evaluate their understanding level, eventual difficulties and, if needed, to use other approaches or distinct teaching strategies. This can also be observed in the first highlighted account, when the student argues that in reading the student's texts "the teacher could also evaluate how his classes were doing and how the students have learned, using it to improve his teaching methods" (QA02). It can be noticed that the student demonstrated to be conscious about the importance of his/her accounts, not only regarding the improvement of his/her own individual learning but as a useful instrument for reflection and overall enhancement of the process.

## Final considerations

This paper aimed to contribute to the reflection about the incorporation of STS focus in the educational context of the secondary school. The results found through the didactical proposal analysis implemented in the chemistry lessons show the potential to promote students' scientific and technological literacy by integrating scientific contents to STS discussions using a socially relevant topic.

The student's narratives point to a significant change in relation to the meaning they then begun to ascribe to the studied knowledge and to the importance such knowledge has to their education as citizens. Among the STS focus incorporation main contributions, we emphasize the perception that, despite the narrow relationship, science and technology present their own interrogations, and are the result of an intricate set of human relations; the increased value of scientific knowledge in daily situations; the development of social responsibility for the discussion of individual and collective decision-making processes in issues that involves science and technology.

In the same way, the involvement in activities makes it evident the good results that can be obtained through participative approach and differentiated didactic strategies, surpassing the lack of interest usually observed in expository lectures, and making explicit the importance of communication skills practice for the systematization of ideas. We especially highlight the 3PM contribution to the organization of the work performed during the classes. In developing the didactic unit, the pedagogic moments' steps were essential for that the students could associate spontaneous concepts with the scientific concepts studied, as well as being free to express their opinion about a topic which they were not familiar with and, still, had a vast impact on their quality of life.

This positive scenario allows us to conclude that the STS focus approach represents a viable pathway for science teaching and learning improvement. Nonetheless, we understand that, as multiple experiences have become denominated STS, and there are different educational views identified under this designation, the challenge to create ways to integrate them in the school involves the consideration of specific guidelines.

Investing in STS focus approach implies, among other factors, analyzing the characteristics of each content and each school's reality, using didactic strategies that value the participation and dialogue, organizing the discussions around a topic that is part of the students' socio-cultural context and, above all, involving a solid theoretical referential to guide its construction and development. In regards to the teachers, we consider that continuing professional development programs are fundamental and they should support them in rethinking about his/her practices and to conceive new perspectives in relation to the role the knowledge acquired in school plays.

We believe that the analysis of each of the aspects and reflections presented here may contribute to the implementation of the STS focus approach, and may indicate pathways to think about educational practices aimed at citizenship education in the current society.

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**Submitted on 15th April 2015**
**Accepted on 12th July 2016**