On teaching chemistry in Brazilian and American high schools: a brief approach

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ABSTRACT

This brief chapter introduces and discusses the issue of the teaching and learning process in Chemistry. Several High School Chemistry teachers have used out-of-date and traditional methodologies which do not fit new pedagogical trends while some neither correlate nor make analogies between topics and students’ everyday lives since they apply the methodology of memorization of chemical and abstract contents. Several studies in the literature have shown that Chemistry teaching must be contextualized and integrate three pillars, i.e., theory, practice and everyday life. Teachers who do not know how to stimulate and motivate students to study Chemistry have drawn the attention of researchers in the teaching area. In contrast, all Chemistry teachers should know how to identify difficulties and pedagogical limitations in order to search for new teaching practices to improve their students’ learning and stimulate knowledge construction. Even though traditional teaching has predominated, new methodological conceptions have introduced different ways to look at Chemistry teaching and raised interest in the area known as Chemistry Didactics. Thus, this text aimed at investigating difficulties in Chemistry teaching and learning by carrying out a brief bibliographical review and collecting teachers’ reports. Some attractive solutions were proposed to make the teaching and learning process easier and improve teacher-student relationships, which have been negative in many cases. In short, teachers must think, study, update themselves and search for a way to make the teaching and learning process in Chemistry useful in everyday life.

# INTRODUCTION

A lot of information has been available in modern society, even though it has not always been well addressed. Schools have been in charge of meeting the high requirement for knowledge and transfer it to students. Therefore, most teaching has been carried out by teachers who, in the development of technical-scientific knowledge, aim at boosting their students’ skills continuously, a task that usually requires broad and contextualized work (NUNES & ADORNI, 2010).

It has often been observed that, mainly in Chemistry teaching, students can neither learn nor associate contents with their everyday lives; as a result, they lose interest in the topic. It is worrisome and shows that teaching has frequently been decontextualized and disconnected from other academic disciplines (NUNES and ADORNI, 2010).

It has been known that teachers are not always ready to work in an interdisciplinary way to associate contents with student’s reality. Even though coursebooks may be – and have been – used as educational instruments that help educators organize their ideas, assimilate contents and teach them to students, teachers should avoid using them as their only teaching resource (LOBATO, 2007). The following motto has been used in Brazil: “teachers should adopt a coursebook but should not be adopted by it”.

Therefore, talking about Chemistry Education is needed so that the teaching and learning process can be prioritized in a contextualized, problematized and dialogic way to stimulate thinking and make students perceive the socio-economic importance of Chemistry in a technological society in a world of constant change (SANTOS & SCHENETZLER, 1996).

Taking this issue into account, the teaching and learning process, along with its difficulties, should be analyzed and the following questions should be answered: what are learning difficulties?; what are the main causes of learning difficulties?; and which factors hinder the teaching and learning process in Chemistry?.

Learning takes place throughout the interpersonal and intersubjective relationship among students, teachers and the object of knowledge in a dialectical relation which has cognitive, affective, psychomotor, pedagogical, neurological, social, historical and cultural dimensions; thus, a relationship based on dialogue and mutual trust is needed to continuously provide means for teachers’ and students’ critical and human development (VYGOTSKY, 1987).

In some schools, teachers keep emphasizing content transference and memorization of facts, symbols, names and formulas, rather than construction of scientific knowledge and connections between knowledge in Chemistry and everyday life. This practice influences students’ learning negatively, since they cannot perceive relations among what they study in class, nature and their own lives (MIRANDA & COSTA, 2007).
The literature shows that, in their professional environment, Chemistry teachers still tend to teach their discipline in a traditional way and use lectures which are not very attractive to students since they are not interested in memorizing the periodic table of elements and contents that are too complex for them to understand. Dictionaries have defined Didactics, whose origin is the Greek word *didaktiké*, as the art of teaching. To make this art help students learn Chemistry and understand its importance in their personal and professional lives, teachers must also be updated in terms of what takes place in this science that is constantly evolving (BERTON, 2015).

Besides questioning the reason why Chemistry is taught in High School, teachers should aim at understanding the following issues: *What is Chemistry teaching that prepares for life?*; *How can teachers help students understand material and phenomena that constitute and transform the world we live in?*. It may refer to learning about compounds found in any material, such as air, water, soil, food, medication, fabric, toothpaste, detergent, shampoo, fuel, dye and packaging, while their properties and interaction with other material/compounds and the environment are observed. It may also mean knowing and interacting with the environment critically and responsibly (KHANAM, 2018).

According to Menezes (2012), teachers should start the school year by planning their work with every class based on mean expectation on future students’ maturity, skills and previous knowledge. However, work has to be continuously reformulated because High School students that compose a certain class are different, a fact that means that all classes are different. Thus, teachers should prepare themselves to teach heterogeneous classes, rather than complain about them. To take into account their diversity is an essential condition to be able to teach.

Considering these worrying facts, this brief chapter aims at systematically understanding factors that hinder the teaching and learning process in Chemistry and at helping teachers find and reflect on effective pedagogical techniques to teach this science in High School classes.

### CORRELATED STUDIES

According to Rice (2002), teachers must better acknowledge and use new discoveries, knowledge determinations, relations and applications, develop new hypotheses and theories and be able to teach it all to students precisely and intelligently.

To make students involve themselves significantly with different approaches of Chemistry teaching would be a way to help them better understand what they are learning and to see how it applies to the world. Students need to become scientifically literate citizens with potential to decide whether they want to choose a career in the Chemistry area and, mainly, to be capable of solving problems in the real world (STAMMES et al., 2020).
Chemistry, just like other sciences, exerts great influence on everyday life; thus, its study is not limited to research in laboratory and industries. When teaching this discipline, teachers should contextualize the fact that Chemistry plays a role in everybody’s daily lives and touches them in some way. One of the strategies that must be used as soon as students start attending the discipline is to read a text with them or bring examples of Chemistry in their everyday lives so as to stimulate them to debate as a group, find Chemistry in their lives and express their ideas. Students get very enthusiastic when they perceive that their concept – or pre-concept – is the same that is introduced by their coursebook and scientifically proposed by their teacher (TREAGUST et al., 2000).

Teachers may use many ways of teaching and many teaching strategies, such as lectures, dialogic classes, dramatization, text/paper reading, problem-solving, seminars, surveys, case studies, brain storming, trial simulation, games and ludic activities (PRIESS, 2012). Even though several strategies may be used to teach Chemistry, teachers may – and should – innovate new teaching techniques while keeping in mind that “memorized knowledge is not knowledge”.

Teaching strategies should also improve the following aspects: learning how to know, learning how to do; learning how to live with others and learning how to be (PRIESS, 2012). Firstly, Chemistry teachers may introduce contents in lectures while stimulating students to learn how to know and understand the essence of concepts under study, rather than trying to memorize them. In Chemistry teaching, it is very important to bring practical experiments to class to enable students to learn how to do. As a result, students learn how to live with others, since they also understand how to work as a team and get enthusiastic about this science, a fact that leads to professionals that learn how to be.

Despite some important projects found both in Brazil and in other countries (such as the Chemical Bond Approach (CBA), the CHEMstudy and the Nuffield Foundation Science Teaching Project, from the USA, translated into Portuguese), little effort has been made in the area. These projects have certainly brought innovation in terms of sequence and valorization of certain contents. However, in general, Chemistry teaching in High School keeps far away from students’ reality. Its curriculum is based on contents, knowledge is essentially academic and the methodology highlights memorization of formulas, concepts, classifications, rules and repetitive calculi which just seem to be useful to make students get good grades (SCHNETZLER & ARAGÃO, 1995).

Chemistry teachers have had much technology to help explain, contextualize and make a difference in this discipline. Therefore, certain practices, such as debates, case studies, demonstrations of Chemistry in everyday examples, reading of papers that deal with the issues under study and educational and fun videos that make students understand the essence of
their study. Internet has helped teachers to stimulate students’ active participation; for instance, when teachers mention a concept, students look for a text or a video in Internet and discuss it and, as a result, they make the teaching and learning process get more dynamic without noticing it (SEERY, 2013).

This chapter invites Chemistry teachers to reflect on their educational practices and their way of teaching Chemistry and making their students actually learn. That is why this chapter encourages teachers to answer the following questions: “Are students learning or memorizing?; In case students do not attend college, will this content also be important in their lives?; Considering the time I have, is it really important to ensure that students study orbital models, hybrid orbitals or any other specific topic?; If I teach everything that my students need to attend college, will they succeed?; Which competence and skills can my students reach if they study all concepts that I want and need to teach?; and Have I been able to develop the competence and skills that my students need?.

METHODOLOGICAL DEVELOPMENT

Bardin’s Content Analysis (1977) was the instrument of data analysis. It is a technique of data interpretation – based on discourse decomposition – which objectively and qualitatively describes content expressed in communication. It enables main concepts and themes to be identified in a certain text and subjects’ utterances to be reconstructed.

RESULTS AND DISCUSSION

Brazilian Chemistry Education – an overview

In Brazil, few High Schools teach Chemistry classes which highlight practice, even though this science is essentially experimental. Many schools do not even have Chemistry, Physics and Biology laboratories. However, some Brazilian schools have a laboratory which is shared by the three areas for practical classes. High School students’ low performance in Chemistry is a well-known fact in the country. Causes which are often considered responsible for this uncomfortable and afflictive situation are some teachers’ professional unpreparedness, lack of opportunity to get updated, low salaries and lack of material conditions in most schools (EVANGELISTA, 2007). It should also be mentioned that many teachers are real heroes who have overcome several barriers in this complicated scenario and have been capable of teaching quality classes.

Teaching Chemistry in Brazilian High Schools merely seems to discover students’ cognitive stages and, consequently, try to adapt contents that have to be taught. Teaching has
been mostly verbal, which leads to mere information transfer, while learning has been seen as a process of knowledge accumulation (TFOUNI, 1987).

To become effective and adequate, Chemistry teaching must be problematizing, challenging and stimulative so as to reach its aim, i.e., guide students to construct scientific knowledge. By no means should it be conceived as teaching that simply introduces closed-ended questions. Chemical knowledge must be introduced to students in a way that enables them to interact actively and deeply with their environment and to understand their roles as actors and stewards in the world.

In order to contribute to solve issues in Chemistry teaching, some scholars have brought up relevant questions about new methodological conceptions that could improve it. Eichler (2007) mentioned that some actions have tried – and should keep doing it – to re-structure methodological and curricular bases of the Brazilian educational system so as to improve Chemistry teaching in High Schools. An alternative could be the use of material prepared by teachers to develop the main contents of the discipline.

According to Evangelista (2007), one of the main objectives of the discipline is to make youngsters acknowledge the value of science in the search for knowledge of reality and to use it in their daily lives. Thus, Chemistry teaching should be conceived as a research process, considering that topics under study constitute problems that need solutions. Stages of the teaching process are the ones of the research process, i.e., problem determination, data collection, hypothesis formulation, experimental work carried out by students and teachers and acceptance/rejection of hypotheses.

Hartwig (1985) stated that assimilation of chemical knowledge consists of concept construction (qualitative principle) followed by numerical identification (quantitative principle). He added that this sequence must be respected, no matter if knowledge is developed empirically or theoretically.

According to Chassot (1990), the reason why Chemistry is taught is the formation of conscious and critical citizens. The author states this science must be understood as: “Chemistry is also a language. Thus, teaching Chemistry must make reading the world easier. Chemistry is taught to enable citizens to better interact with the world”. In Brazil, the number of studies that focus on Chemistry teaching has increased since the 1980’s. Researchers have constantly aimed at investigating teaching processes intertwined with students’ daily lives and their social factors.

Other scholars, such as Maldaner (1998), believe that quality Chemistry teaching should search for a methodology that favors experimentation/practical teaching. This form of knowledge acquisition enables students to critically reflect on the world. Besides, students’
active, creative and constructive involvement in contents addressed in class develops their cognitive skills.

Mortimer (1992) advocated the notion of epistemological profile in order to overcome inappropriate perceptions in Chemistry. From this perspective, the approach of contents uses the history of Chemistry as the basis and guiding axis of the teaching and learning process. The author also states that facts that led to this knowledge production throughout history reflect their essentially dynamic aspect. The methodology that uses the history of Chemistry aims at going beyond traditional and dogmatic teaching which has still been deep-rooted in Brazilian High Schools.

Regardless of the methodological conception, knowledge developed by Chemistry teaching must be based on strategies that stimulate student’s curiosity and creativity to awaken their sensitivity to invent and understand that this science and its knowledge permeate their lives and can be found in the simplest everyday phenomena (ASTOLFI, 1995).

However, these ideas may bestow some intrinsic reductionism to research in Chemistry teaching, which restricts it to mere speculation and application connected to the psychology of science. On the other hand, this historical knowledge enables the development of Chemistry Didactics, which is essential to any teacher. Teachers are told to use their own theories and models as another scientific area of study and investigation, besides promoting consensus to develop researchers in Chemistry teaching (SCHNETZLER, 2002).

The milestone in Chemistry teaching in Brazil is the fact that important researchers in this area reinforced their studies in order to: encourage research and knowledge production in Chemical Education by promoting scientific meetings; join professionals who are interested in research in Chemical Education to present and discuss results of their activities and share experiences; create opportunities to disseminate results of studies to enable Elementary and High School teachers and professors to learn about methodological renewal and update their knowledge in Chemistry, besides proposing solutions to issues in Chemistry teaching, mainly in public schools; and constitute and publicize national and international production in Chemical Education so that researchers, teachers and teachers-to-be can use it to improve the quality of teaching and research in the country (Schnetzler, 2002).

**American Chemistry Education - Through the lens of a Minnesota educator**

Throughout reading this section, it is important to remember that this is just a snapshot of the American education system, and only gives one perspective. Throughout my 9 years spent in the Chemistry classroom, best practice pedagogies have shifted. During my licensure program, we focused heavily on inquiry-based learning. “Inquiry-based science adopts an investigative approach to teaching and learning where students are provided with opportunities
to scrutinise a problem, search for possible solutions, make observations, ask questions, test out ideas, and think creatively, and in so doing, learn to reconcile their developing understandings with previous knowledge and experience” (GILLIES, 2020).

The American Education system does in fact set up teachers up for success in inquiry education. For the most part, all chemistry classrooms come equipped with a laboratory, glassware, chemicals and tools. The subject lends itself well to inquiry because of its lab-based nature. As a teacher, it was important to include self-discovery in labs. During my teacher training, we practiced taking cookie-cutter labs and including more inquiry and changing questions into higher order thinking and reflections.

This was nearly 10 years ago. As times change, so do best practices in the classroom. While inquiry-based learning is still extremely important, it has essentially become the norm in the chemistry classroom. A new focus has turned to personalized learning. Personalized learning is a form of pedagogy in which teachers and students essentially carve their own paths towards mastering standards Although this concept has been around for years, it is gaining rapid interest as education becomes more technologically advanced (PANE, J., STEINER, E., BAIRD, M., & HAMILTON, L., 2015).

Some students may learn a concept better by reading while other students may need to hear it orally. With online tools becoming more robust, this is easier and more attainable for teachers. For example in my own classroom, I will give students the choice to listen to my pre-recorded lecture, read about it through the textbook or have a small-group discussion. Students still learn the content, but all in their own unique way. This is also true for showing mastery of the content. For some subjects, I allow students to show mastery by writing or sometimes they choose to verbally explain it. Either way students can show that they mastered the content without always needed to take a standard and traditional paper and pencil test.

Another shift in my own classroom has been a focus on global issues in chemistry. As the world becomes more interconnected, teachers look to include this in their classroom as well. It is important to remember that although Chemistry is a stand-alone subject, it is extremely intertwined with other disciplines. Chemistry requires a lot of writing and communication. Chemistry is the basis biology, while relies heavily on knowledge of physics. Chemistry has been an important part of history - wars have been fought over things like salt and guano. As people look to helping the environment, chemistry is a huge part of climate change. As my teaching practices change, I find it more and more important to include all of these different subject areas. The American education system places chemistry in a one year course, while never formally circling back to any of the content. If we are able to intertwine the subject areas, it is hopeful that students will realize the importance of not only chemistry, but the other subject areas as well.
As I look to the future of chemistry, I look to the new Minnesota State science standards which will be implemented in the next couple of years. It is refreshing to see climate action included, which is something I have focused on. But what is new is the inclusion of Minnesota American Indian communities. For example one standard states, “Students will be able to gather information about and communicate the methods that are used by various cultures, especially those of Minnesota American Indian Tribes and communities, to develop explanations of phenomena and design solutions to problems” (MINNESOTA DEPARTMENT OF EDUCATION SCIENCE STANDARDS). With social issues coming into the science classroom, it will be exciting to see if positive change comes with this new form of pedagogy.

**CONCLUSIONS**

This chapter proposed to trigger some reflection on Chemistry teaching – often decontextualized and aseptic – based on different talks and thoughts. The great challenge to be tackled in classes is to form citizens who are aware of their transformative roles in society. Criticism is welcome! Search for solutions and alternatives, as well! Working collectively and getting involved in social, economic and political issues – to analyse, discuss and change reality – are expected, rather than individualism.

As mentioned throughout the chapter, effort has been made in the search for changes in Chemistry teaching, but it has not always been problematized. In some situations, teachers even carry out teaching plans whose guiding principles are experimentation, History of Science and everyday teaching. However, it has been observed that teachers undertake these principles in agreement with their beliefs, experiences and previous education processes. Therefore, the huge distance between teachers’ early proposals and their real implementation in the curriculum is revealed.

Teachers often see their professional practices as something essentially simple, i.e., knowing some contents and transferring them to students, who provide feedback in texts, projects and tasks, are enough to make students reach what is expected from them (good grades). In fact, teachers’ professionalization is an extremely complex topic that needs further discussion.

In short, when teaching is discussed, teachers state that: “Our fight aims at making teaching less aseptic, less dogmatic, less abstract, less historical and less evaluation-based”. It is feasible to develop and implement a proposal for Chemistry teaching that is more coherent regarding the current economic, scientific, social and cultural context. It should be a problematizing proposal which makes a difference in the environment and treats students as subjects who have knowledge and as essential components of teaching and learning processes.
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