Pedagogic Proposal Focused on Sustainable Development: Fracking, a Matter of Active Debate at Present in the Argentine Patagonia

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Abstract This research focuses on the development of a pedagogic unit on hydrocarbons for the last year of high school students that links the contents of science with social, technological and environmental aspects using a global approach (STES). This proposal emphasizes an holistic view of school contents, selecting a controversial topic such as oil extraction by hydraulic fracture known as "fracking" that arouses a deep debate due to its social implications. This exploratory research uses a qualitative methodology focused on a case study. Empirical evidence is gathered using classroom observations, student surveys and teachers´ interviews. Due to the size of the sample limited to a small group of students, this study does not admit generalizations, it only shows a tendency. This paper is a contribution to future research on STES approach in High School.

Keywords Pedagogic strategy · Fracking · Sustainable development Environment

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1 Introduction

Growing concerns about a threatened environment, conflicts, inequities, poverty, ideological extremes, and consumerism are all indicative of a pressing need to reflect on the global status quo and to find constructive and long-term, sustainable strategies for planet and people. The need to give the younger generation "a better deal" for helping to shape a sustainable world is being embraced by several international associations, NGOs, and multiple sectors of the whole society (Lueddeke et al. 2017). Environment and society are synergistic in any environmental modeling; the reaction of society should be included, and the uncertainties are more of socio-economic nature than biophysics (Lubchenco 1998).

There is a widespread recognition that this century citizen should have a basic understanding of the fundamental concepts and procedures of science and technology because of their ever increasing relevance in his/her common life (Lok 2010). Nevertheless, teachers usually complain on the lack of interest in science of their students. To reverse students' lack of interest in science, several innovative pedagogies are being implemented. Among them the Science, Technology, Environment and Society (STES) and the Inquiry-Based Science Education (IBSE) approaches, are among the most successful methodologies for the teaching of STEM (Science, technology, engineering, mathematics) disciplines (Nudelman 2014).

The STES approach that links science to technology, society and environment has been applied by several research projects since the 1990s and continues to be of interest in science teaching today (Aikenhead 1992; Ramsey 1993; Jiménez-Aleixandre and Gallástegui 2011; Zoller 2013). In the IBSE approach the students are proposed a scientific problem or phenomena and working in a 4-members team they should look for experimental evidences of the STEM fundaments that could explain the observation (Harlen 2010; Nudelman 2016). In both pedagogical approaches the authors agree on the importance of structuring science contents with current problems that may be significant for the students. As a very important example, it is worthwhile mentioning that the need for including the society's impact is an essential requirement in any research on the economy of Global Climate Change when considering the efforts for reducing emissions (Sandmo 2015; Chisari and Miller 2016a, b).

Argentine Norpatagonia has one of the main reservoirs of unconventional hydrocarbons that must be extracted by hydraulic fracture. Fracking is a technique that allows the extraction of gas and oil from the subsoil by deep drilling and injection of high pressure water with the addition of numerous chemicals. This technique is severely questioned due to environmental implications, although it is one of the main sources of income for the region. It is also subject of controversial debates in different areas of society so students are familiar with the problem due to the repercussion in the mass media and social networks. Therefore, addressing this situation from a didactic proposal is interesting and highly convenient to develop critical judgment and environmental awareness.

For achieving the mitigations expected by 2030 (COP21 2015) education is considered a key issue since the young students are being mentioned as the real "agents of change" (Battro et al. 2017).

The aim of this paper is to discuss STES approach in Chemistry classes, selecting a hot topic such as "fracking" to foster skills such as critical analysis and argumentation and make the students aware of their own responsibility as active citizens.

2 Content and Work Development

The public image of Chemistry is fairly lowing down in the popularity stakes, especially because of the contention of the potential harm, to human health and the environment, caused by the application of chemistry. Environmental issues are the subject of countless books, articles, speeches and even sermons, and appear to constitute by far the biggest social challenge chemistry has ever had to face (Russell 2000). This bad image could be justified in some cases due to some mistakes, undesirable side-effects and accidents that have occurred. To face the challenge and overcome the unwelcome opposition, a more environmentally friendly new chemistry has being developed in the academy and in some industrial sectors since almost two decades ago (Anastas and Kirchhoff 2002). This kind of Chemistry is well accepted by the students and lead to a better understanding between environmentalists and chemists, for the benefits of the whole society (Nudelman 2004).

When Chemistry is taught by the traditional way, students get bored by the accumulation of laws, formulae, nomenclature, and so on, that (they presume) has nothing to do with their real life.

Particularly, in The Organic Chemistry Curriculum of almost any High School program, Hydrocarbons is one of the main units, usually teachers place emphasis on disciplinary contents, (structures, nomenclature, sources, etc.) leaving aside other aspects that allow a more global approach. The present proposal focuses not only in scientific aspects like properties and structures of hydrocarbons but also intends to take into account the differences between fracking and other methods for oil extraction, with regard to the environmental impacts.

The country's main geological formation called Vaca Muerta is located in Northern Patagonia, Argentine. It is a shale oil reserve of global importance and its extraction requires fracking. The technique for extracting petroleum and natural gas from non-conventional reservoirs exploits the hydrocarbons accumulated in the pores and fissures of certain sedimentary rocks. These rocks are of fine or very fine grain, generally of lime type, which permeability prevents the migration of hydrocarbons to large reservoirs. It is necessary to drill wells that occupy wide areas; millions of gallons of water must be injected with chemical and toxic substances in order to extract them. The discovery of the shale oil reservoir raises big controversy in different fractions of society. The exploitation of this resource, should bring, a great economic growth to the region but it also has important

environmental implications that should be jointly considered (Brock and Taylor 2004). This technique is also the subject of active debate between those who are aware of the need to apply this methodology and their opponents, very often not well informed about the technological aspects. This research seeks to provide evidence about how the design and placement of a different teaching proposal with an IBSE and STES approach, can improve science teaching. The work proposal prioritizes the use of tools, such as searching and contrasting technical information, search for evidence, critical analysis, argumentation, etc. to discuss viability and consequences of using a highly questioned hydrocarbon extraction technology. Evaluation of the proposal is made by surveys, interviews and class observation. The field work of this research is carried out within the framework of a thesis for Chemistry teachers' training.

3 Teaching Sustainable Development in High School: Argumentation in Science Classes Using a STES Approach

The High School students are aware of these facts that surely will affect their lives in the near future. Very often several newspapers, mass media and social networks refer to the subject exposing very different points of view, usually depending on their own interests. It is expected that an informed citizen should have its own critical opinion on the application of technologies that could affect human life and/or the environment (Binmore 2011). The High School teachers, especially in the science classes, should help students to critically analyze the large body of information, understand the fundamentals of science and technology involved in the suggested oil extraction methodologies to build their own rational point of view. First of all, it is necessary to know about the different types of hydrocarbons, their structures and properties and how they are incidental in the diverse extraction methods in order to have enough background to discuss the topic seriously.

The STES approach that links Science, Technology and Society with environment seems suitable for this purpose, since it gives the chance to apply science contents to everyday problems and make decisions as citizens committed to their social environment. Duran (2013) emphasizes that it is fundamental to understand the centrality of sustainability ethics as a set of values that promote the understanding of the complex interactions between society and environment, taking into account the interrelationship of ecological, cultural, technological, economic and social aspects. We agree with the statement by Ramsey (1993) "From the perspective of social responsibility, scientific training should give rise to students who can and do participate in the resolution of social issues related to science. This means that students are willing and able to act effectively as citizens using the values and skills that come from both science and democracy". In STES science teaching, science content is certainly taught but from a social perspective that allows them to have an up to date view of science possibilities and limitations. To ensure sustainability of

natural resources must be a priority in science teaching. From the perspective of sustainability, any relevant, generated or acquired knowledge that is put into action in the STES context should be guided by the idea of social responsibility (Zoller 2012). That is why choosing a relevant issue to discuss in class helps students develop different skills like argumentation in order to analyze data, draw conclusions and communicate effectively. When the students use IBSE methodology they look for experimental evidence, contrast different explanations of a phenomenon, theory, or model by evaluating evidence and drawing conclusions, they are using argumentation (Nudelman 2016). Definition for this practice is quite clear. We conceive argumentation as a mean to evaluate knowledge statements, hypotheses conclusions or theories based on available evidence. What we understand today as an effective science learning goes beyond understanding and using scientific concepts and models. It also includes participating in scientific practices. These practices correspond to the way scientific community works, creating new knowledge (Jiménez-Aleixandre and Gallástegui 2011).

Both, from the curricular documents that come from the Argentine Ministry of Education, called Priority Learning Issues, (NAP in Spanish) and from didactic research, argumentation is valued as a relevant competence in Science teaching. Pedrinaci (2012) says it contributes to develop responsible citizenship, able of participating in social decisions using critical thinking. The use of fracking, suspected of producing high pollution in watercourses, is a good point to start a debate. It is necessary to consider the non-renewable character of oil, to compare pollution generated by the different methods of oil extraction, sustainability in resource management, and be aware of economic-social impact. Jiménez-Aleixandre and Gallástegui (2011) associate argumentation to many purposes of science teaching, that help students develop the following skills:

- improve learning processes.
- responsible citizenship, able to participate in social decisions by exercising critical thinking.
- participate in scientific practices that expand scientific competences and allow an understanding of the complex nature of science.

Undoubtedly, the promotion of IBSE and STES-focused education for sustainability in science education, at all levels, raises the issue of education versus indoctrination. In this context, science teachers' job is not to tell the students what to think, but rather to develop their own thinking (Qablan et al. 2011).

4 Research Methodology

This is an exploratory study based on a qualitative methodology.

The researcher takes the role of participant observer in the present case study, to obtain information about the students' perception about the motivation, significance and importance of STES approach in chemistry classes. The emphasis of this

didactic proposal is placed on communicative skills such as argumentation and critical judgment development. Cognitive processes developed are collected through analysis of student outputs. This didactic strategy will allow students:

- Relate disciplinary contents about hydrocarbons with technological, social and environmental aspects.
- Develop informative, communicative and argumentative skills.
- Critical thinking for the detection and analysis of manifest trends in different sources of information.
- Creativity to design their productions in different communication formats that make the community aware of relevant environmental issues.

This strategy is tested with thirty two senior students of a private high school.

After learning usual science contents like properties, structure of hydrocarbons and fractional petroleum distillation, students are asked to search scientific literature and identify recent articles that address the problem of fracking to exploit shale oil resource. After discussing in class several articles and different visions of the problem the students are organized into groups with different number of students each, in order to be part of a role playing process where they have to develop arguments in favor and against fracking and communicate their conclusions to peers. For a convenient support they have to seek information from different sources like non-governmental organizations, environmental forums in Internet, oil companies, government offices, and analyze the information with critical thinking.

Group 1 (10 students) have the task to prove that fracking is a convenient solution for the region and bring up reliable information from different sources. They have few minutes to present their idea using Power point or Prezi in sub-groups of two students.

Group 2 (10 students) have to support the opposite idea in the same way as group one.

Group 3 (5 students) have to record all relevant information in the debate for a report.

Group 4 (2 students) present each speaker, moderate and keep discussion under control, same chance to speak with equal exposure time. Read the final conclusions.

Group 5 (5 students) have to play the role as reporters, take pictures and record some main ideas and then write an article for the school on-line newspaper.

Students from another course of the same school, with their science teacher, are invited to play the role of audience and choose which they think, is the most convincing posture.

Once everyone had the chance to speak, and defend their judgment, the audience composed of peers express their verdict based on what they heard and considered more credible. They write down their position and hand the paper to the moderators who take their time to order the answers and then read the conclusions aloud, ending the session.

After the unit is finished all students answer surveys that have to do with learning and motivation. An interview is made to the science teachers who participated as audience.

5 Results and Conclusions

92% of the students answered that they liked the way the unit was taught.
3% didn't like it.
5% didn't answer.
Of those who answered yes,
20% said they liked because they learned new things about oil extraction.
25% because the new skills are very important for their future.
30% care for social responsibility.
15% considered an important issue because they live in a state whose main wealth is oil and need to make use of the resource in a sustainable way.
5% liked role playing and argumentation as a technique that allows learning and making decisions.
5% did not answer.

Students were positive about their learning process and were aware of advantages of argumentation. They feel worried about their future and also responsible for making decisions that will preserve environment and its natural resources. They also know that oil means money and the state depends largely on this resource.

Class observation reveals that students took role playing with great concern and studied more than in a traditional class to be able to communicate conclusions. The reports and the newspaper article were considered by the teacher as very satisfactory.

Interview made to the High school science teacher who participated in the audience revealed that she was surprised by the quality of the arguments made up by students and by the realism shown during the role playing.

We can finally say that developing science classes that ensure the use of scientific competencies such as argumentation in a curriculum with a STES approach, allows us teach science in a more profitable way and promote sustainability.

Sustainability science is a rapidly evolving area that challenges professionals and academics from all scientific disciplines to apply their expertise to promote sustainability (Clark and Dickson 2003).

Lozano and Watson (2013) prevent that participation of chemists in the collaborative field of Sustainability science is critical for developing and implementing sustainable stratagems for dealing with complex global dilemma.

We believe that is true not only for Chemists but also for Science teachers who are educating the new generations to make decisions that compromise the future of society (Nudelman 2017). It is urgent to update the science curricula to emphasize

sustainability and involve students as the real "agents of change" for achieving the United Nations Sustainable Development Goals, UN SDGs, proposed for 2030 (Nudelman 2016).

This proposal aims to be a contribution to deepen the disciplinary contents and rescue competences such as writing and speaking in science. It also highlights the importance of disseminating regional environmental issues in the community using different communication formats.

Analysis of surveys show a substantial increase in student motivation by this type of proposal, focused on real issues that involve technological as well as social and environmental knowledge. The scientific procedures applied in the classroom, such as multiple variables analysis, well-founded conclusions and argumentation were mentioned by the teachers as very important. They also considered that the performance of the students was much better than in the traditional science classes.

Like all case studies, this research only shows what happened with this particular group of students and marks a trend that may be insured by future and larger studies.

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