

Nitrate Contamination of Bottled Water: Description of a Project-based Learning Experience

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ABSTRACT

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The objective of this work is to describe a project-based learning experience carried out with students of an assistant training course. Students had to design a project to establish nitrate contamination of bottled water, analyse the reasons why people consume bottled water and their perception about its quality. For this purpose, a survey and a sampling plan was planned and executed. The survey was answered by 364 people. A total of 200 samples were obtained from 20-liter containers. Results were discussed and presented in a scientific reunion. Strategies to employ the data obtained and the methodology used in undergraduate courses were proposed.

Keywords: project-based learning, bottled water, public health

INTRODUCTION

In the Chair of Public Health and Environmental Hygiene different subjects are taught for both pharmacy and biochemistry students. Some subjects are compulsory, other elective. Also, the number of students varies greatly, from less than ten in the elective subjects or the training course for assistants, to more than one hundred for the grade courses for pharmacy or biochemistry. In addition to regular courses, a training program is offered for those who want to participate as assistants in the future. Although the contents of some of these subjects are shared, the depth in which they are presented and analysed is different according to each case considered.

Water hygiene is one of the topics shared by several subjects. In fact, the study of drinking water quality is one of the most relevant topics in any public health course. The improvement in water access and sanitation conditions explains a significant fraction in the increase of life expectancy in the last century and it is still currently a central objective in plans for future development, for example in the Millennium Development Goals of the World Health Organization (WHO, 2013).

There are some recurrent problems regarding teaching practice that have been detected over time. One of

them is how to convey to students the great importance these facts have in real world, especially in our country. For example, considering water access, in Latin America and the Caribbean 7% of the population does not have access to improved water sources. Even when this data is better than those observed in other parts of the world, it still shows that a high percentage of the population lives in conditions that do not guarantee their right to health. There are also important gaps in access levels between different sectors of the population, for example in between countries, between different regions within a country and between sectors of the population according to their income level (PAHO, 2011). Students of Buenos Aires University come mainly from the Autonomous City of Buenos Aires, one of the most privileged zones of Argentina, with an access to drinking water supply close to 100%. This means that public health problems related to the access to safe water sources are relatively unfamiliar to their personal experience.

A second challenge is how to show the multidisciplinary nature of public health, a not so simple task in a faculty where hard sciences prevail. Traditionally public health focused on assuring safety of water and

food, improving sanitation and providing immunization. Chemistry, environmental engineering and immunology, among other branches of science, are centrally involved in the solution of these problems. But today a broad agenda for Public Health exists, more related with social sciences, including topics such as elimination of health disparities or the address of the effects of globalization (Institute of Medicine-US, 2003). Continuing with the focus on water for consumption, the role of the pharmacist and biochemist in the area includes not only the analysis to verify its quality. In public or private institutions, they may be responsible for providing advice on water safety. They can also perform outreach tasks in the community with the aim of reducing the incidence of waterborne diseases. The new approach of public health requires well-trained professionals, capable of working interdisciplinary, which focuses on population health, understanding not only the effects of biology and behaviour, but also the social, environmental, and economic contexts within populations exist (Institute of Medicine-US, 2003).

Finally, another question has to do with the contents shared between the different courses. The topic of water quality is presented in the general degree courses, in which there are more than one hundred participants. Water quality is also studied in elective subjects and finally in the courses for assistants. In both cases the number of participants is much smaller. Although shared contents were presented with different depth or showing different aspects in the different courses the differences were not so substantial. A student who goes through the different stages encounters something that is not much more than a repetition of the subject. In all cases, the approach was that of a traditional class and no advantage has been taken of the possibilities of working with smaller groups that are simultaneously more committed to learning.

To try to solve these problems different strategies had been implemented in the last years.

One of them was the use of the case method. Students, taking the role of a laboratory analyst, would give their recommendation for a series of water analysis. Problems resolution included the consideration of social aspects which in a traditional class did not show up in the discussion. For example, from the scientific point of view if a water sample does not comply with a limit value the recommendation would be not to consume this water. That may be true for the water of an industry. However, there are cases in which the people who bring the sample have no possibility of having better quality water. Here the analyst, despite poor water quality, must fulfill the role of advising people if there is any treatment available to transform the water into safe.

Another useful strategy was to carry out the analysis of

nitrate in water samples taken from each student home. Results obtained showed the extent of nitrate contamination in groundwater of the area. Both strategies have allowed students to feel water pollution problems as something closer to their reality. The description of these experiences has been recently published (Gallego et al., 2016).

Although in some of the cited cases students were involved in data generation, it would be interesting, especially for the most advanced courses, that they could also take part in the project design.

Project-based learning (PBL) constitutes a strategy based on study and personal experience since it is the student who, under instructor supervision, must execute the entire activity (Izquierdo, Benítez, Berenguer, & Lago-Alonso, 2016).

Thomas (2000) found five criteria for identifying characteristics of PBL:

Centrality: PBL projects are central to the curriculum.

Driving question: The projects should focus on questions or problems that “drive” students to encounter the central concepts and principles of a discipline.

Constructive investigations: The central activities of the project must involve the construction of knowledge by students.

Autonomy: Projects are student-driven to some significant degree.

Realism: Projects are realistic or authentic, not school-like.

Although PBL is usually presented as an innovative methodology, it must be taken into account that the basic concept and tenets of “learning by doing” have been practiced in the education realm since the earliest days of formal education (Tan & Chapman, 2016). PBL use has extended to all fields of science. PBL has been employed in fields as diverse as linear algebra (Izquierdo et al, 2016), geography (Bowlick, Bednarz, & Goldberg, 2016), or chemistry (Barak & Dori, 2004). Strategies bases in PBL were employed to train teachers with very different purposes, for example, for the integration of educational technologies into their teaching practices (Chen, 2011) or for the development of strategies for the prevention of drug abuse (Amnesty & Páez, 2018).

The objective of this work is to describe a project-based learning experience carried out with students of our assistant training course. The theme chosen for the project was the evaluation of nitrate contamination in bottled waters sold in the area. Nitrate is one of the few chemical water pollutants that can cause acute toxicity. As it was previously stated, students had already done the evaluation of nitrate pollution of water obtained from their own home. If any student found a contamination, one of the

alternatives suggested was to buy bottled water. Bottled water is supposed not to be contaminated. But, since bottled water can be obtained from a ground source, it could be suspected that nitrate contamination can affect this product as well. The project is a continuation of what has been seen in previous courses. Moreover, it is also expected that results obtained can be further debated by other groups of students.

METHOD

The first step was to make an open call to the students who passed the biochemistry course to participate in the training course for assistants. The call was made at the end of the biochemistry degree course in 2017. The experience was carried out throughout the year 2018. A total of 12 students were registered, 11 of them from the biochemistry career and one from the pharmacy career. There were 9 women and 4 men, a proportion that can be considered similar to what exists in the degree career. All the participants had completed the public health degree course and were in the final stage of their careers, this means that they had sufficient knowledge of statistics, analytical chemistry and microbiology. None of them had work experience in laboratory tasks. This training course was organized as showed in [Figure 1](#).

Initially an intensive water workshop was held, mainly in the laboratory. The workshop lasted four weeks, during which the students were trained in the different methods

applied to the physical, chemical and microbiological analysis of water. Special significance was given to the meaning of the presence of nitrate, the contaminant chosen for the subsequent sampling work, and the techniques employed for its determination. The objective of this stage was to train the students in practical work in the laboratory and to select the method that would be employed for nitrate determination.

The second stage of the work was done in a virtual classroom, using the Google Classroom tool. The discussion focused on the experimental design. Particularly the challenges for this stage consisted in how to obtain information about the consumption habits of bottled water, as well as the perception of people about its quality. Finally, the most important part of the design was to establish the sampling plan for the evaluation of nitrate concentration in bottled waters. The design also implied thinking about how the information obtained could be returned to the community. Google Classroom was used to host the links to the different documents shared through Google drive. The form tool was used to prepare a survey. Google Sheets was employed to record the nitrate values of the samples. In order to share the results with the participants, a web page was created in Google Sites, where the links to the survey, the spreadsheet with the obtained results, and additional information were placed.

The last step of the proposal was the analysis of the data obtained to elaborate the conclusions. It must be

Start date	STAGE	Activities and contents
march 2018	WATER WORKSHOP	
	<i>Classroom classes</i> 5 Sessions - 20 h	Water sources Chemical and microbiological contamination of water
	<i>Practical work in the laboratory</i> 5 Sessions - 20 h	Discussion and training in the methods used for water analysis
april 2018	PROJECT DESIGN	
	<i>Discussion in Google classroom</i> Virtual - 4 weeks	Survey design Sampling plan design
may 2018	FIELD WORK	
	<i>Practical work in the community and in the laboratory</i> May to september	Sample collection Sample analysis
june 2018	DATA ANALYSIS	
	<i>Face to face discussion</i> Meetings scheduled according to need May to october	Interpretation of the results Adjustments in field work
october 2018		

Figure 1. Course organization scheme: stages and objectives

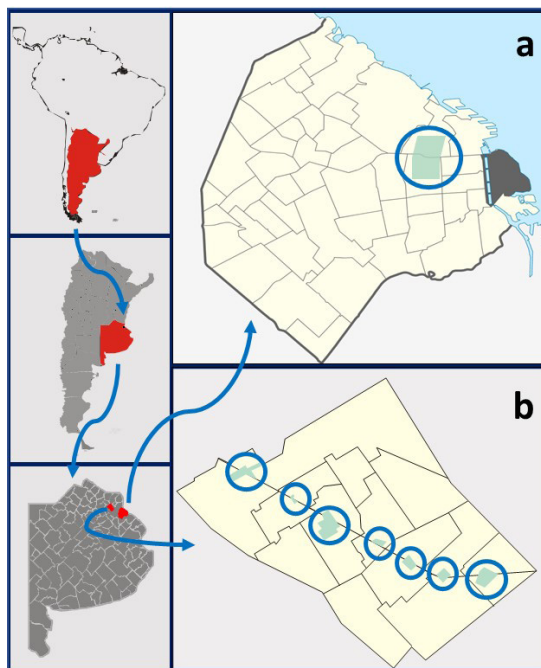


Figure 2. Location of the sampling areas (circled)

a) Autonomous City of Buenos Aires b) Municipality of Malvinas Argentinas

considered that this is a true research project which its results can be presented in the corresponding scientific fields. But in this case the activity did not end with the results. One of the tasks programmed for the participants consisted to critically analyse the activities carried out. The students also had to propose or generate didactic material from obtained results, which could be used by the students of other courses.

RESULTS

Intensive Workshop

The course began with twelve students. In the water workshop they discussed the fundamentals of the methods used for water analysis, particularly for the determination of nitrate. They had to look for the different methods and evaluate their pros and cons in order to apply them in the laboratory. The main bibliography analysed was “Standard Methods for the Examination of Water and Wastewater” (APHA, 2012), not only the current edition but also previous ones, which purposely gave an idea of the diversity of available methods and how, for different reasons, they lost validity. Considering that it would be necessary to analyse many samples, the UV screening method for nitrate, simple but not specific, was chosen. In addition, a commercial kit based on a specific method for the compound was selected for the confirmation of obtained results. The kit employs reactive strips and is therefore fast and easy enough to process numerous

samples. An alternative specific method based in the reaction of nitrate with brucine in the presence of concentrated sulphuric acid was discarded, due to reagents dangerousness. Once the method was selected, the students were trained in the preparation of the required reagents and in the practical implementation of it.

The current legislation for drinking and bottled water in Argentina and in the world were also analysed. Unlike what happens for other compounds, there is an international consensus on the maximum values established for nitrate. The maximum value for nitrate in Argentina’s legislation is 45 mg/L.

The Project Design

The project design was the core of the experience. In order to obtain information about bottled water consumption and perception about its quality, students developed a survey using the Google Formulary tool. The first section of the survey seeks to collect data on age, educational level and address of respondents. Then they were asked about frequency of consumption, the reason why they consumed bottled water and how its quality was considered in comparison with tap water. If someone responded that they did not consume bottled water, they must tell the reason, and the same if someone preferred it to tap water. The form was delivered to the people who participated in the sampling stage and distributed via social networks.

A total of 364 answers were obtained. Most respondents (71.7%) consumed bottled water frequently, generally because it was considered healthier. In fact, 82.4% considered it to be of better quality than tap water, especially purest (25.6%), safer (27.0%) and with better taste (34.4%). Only 49.8% read the label of the product and 64.8% confessed not to know what its origin was. As for the people who did not consume it, the majority 60.2% did so because they have tap water.

The sampling design presented more problems to the students. The idea of sampling water in shops instead of homes was imposed, due to easier access. In Argentina, it is common for stores to have large volume water dispensers (20 L) for consumption both by the owners and by the customers. The same bottled water brands are also consumed by people in their homes. Another important decision was to choose the area to be sampled. It was decided to start in an area located close to the university, in the autonomous city of Buenos Aires, the capital of Argentina. It is the area with the highest income in the country with coverage of water access close to 100%. A random sampling plan was made for two neighbourhoods, belonging to communes 2 and 3. Both communes are close to the university, but they have very different characteristics. Commune 2 corresponds to the neighbourhood of Recoleta, one of the most exclusive residential areas of the capital. On the contrary, commune 3 corresponds to the Once neighbourhood, an area of commercial deposits and wholesale businesses. The location of the sampling areas can be seen in [Figure 2](#). The green area corresponds to the zone where the sampling was carried out.

For the randomization of sampling, 100 random blocks were selected, and a sample was taken from each of the selected blocks. A total of 100 samples corresponding to 36 different brands were taken. Despite the differences between the two sectors, all the samples presented nitrate values within the legislation limits.

Subsequently, a second sampling was carried out in the Municipality of Malvinas Argentinas. The area is in the neighbouring Province of Buenos Aires, about 30 km from the capital. In the area, access to water reaches only 7% of the population. The randomization of the sampling was carried out in the same way, but restricting the areas to those categorized as commercial, where it was possible to find shops ([Figure 2](#)). The green areas correspond to the sampling zones. In Malvinas Argentinas there are no large commercial areas, but small centers located around the seven existing local train stations. A total of 100 samples were taken also here, in this case corresponding to 41 different brands. In this case, it was observed that 25% of the brands presented higher values than those established by the legislation. The values obtained for some of the

samples exceeded 200 mg/L.

In the group discussion it was proposed to also use the sampling stage as a mode of education to the community about water quality. The groups who carried out the sampling stage were constituted by one or two students and a more experienced teacher. In each place a presentation of the project was made, clarifying the nature and importance of the problem that was being studied. In addition, a web page was developed with information not only about the project but about general topics of water quality, so that participants could continue reading. On the same page results were reported and the link to the survey was left. On the website was also the email of the teachers in charge of the project for any further consultation. The URL of the webpage created for the feedback of the information is: <https://sites.google.com/view/cursowebnitrate/página-principal> (in Spanish).

Analyzing the Results

The results obtained were interesting and show an obvious correlation between access to water in an area and the quality of the bottled water sold in it. But understanding the reason of this correlation was not so easy. A broader discussion of the technical aspects of nitrate pollution and of the control strategies applied by the state to the companies that sell bottled water is beyond the scope of this paper. People's preference for bottled water is in accordance with previous research (Delorme, Hagen, & Stout, 2003). The students summarized and discussed the results in order to present the experience in a scientific reunion. Finally, results of the project were presented in the Second International Environment Conference that took place in the city of Tandil, Province of Buenos Aires in October 2018 (González et al., 2018) Students who participated in the experience appear as co-authors of the research work together with their teachers.

At the same time, strategies for using these results in subsequent courses of the subject were discussed. One of the proposals was to repeat the experience in the undergraduate course by analysing samples of bottled water collected by the students themselves.

DISCUSSION

The workshop held at the first stage of the work does not represent a novel approach, since they consist of conventional classes where the topics were discussed, but it was necessary for the basic formation of the students. However, there are some points that deserve to be highlighted. According to the experiential learning theory, learning is the process of creating knowledge. This constructivist approach is opposite to the transmission model, where fixed ideas are transmitted to the learner

(Kolb & Kolb, 2009). The methods used for water analysis evolve, as does knowledge, and students usually receive them as something finished, as if they were static and immutable. Methods also don't always work for any situation. Moreover, in many countries in the region, including Argentina, another fact to consider is that many laboratories do not have all the necessary equipment, or cannot assume the cost of some of the reagents. It is important therefore to learn to choose the most appropriate method for a given situation. Another important lesson is to learn how to implement a certain method. Usually in the practices that are carried out in our faculty, the reagents are already prepared, and students just follow a recipe. Performing the preparation and overcoming the unexpected difficulties that can arise is also relevant learning. Finally, another task that our students seldom do is to look for the legislation applicable to a certain situation and compare it with the one in force in other jurisdictions. Analysing the variations presented by different standards allows highlighting the scientific uncertainties that underlie for the value assigned for that parameter.

The second stage consisted in the development of the project. Project based learning proposes to involve students in the development of a genuine investigation project (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000). This teaching method is characterized by authentic investigation, the production of an end-product, collaboration among peers, and the use of technology to support the process of inquiry (Barak & Dori, 2004). PBL is believed to foster the development of sophisticated understanding of a content, a necessary skill for an assistant training course. Students must develop strategies for information processing, communicating, critical and analytical thinking, collaborating, and self-evaluating which are essential to fulfill the diverse needs of their future role as teachers (Chen, 2011). Environmental practice has long been recognized as being important within environmental education, whereas social interactions can be a positive force for environmental identity development (Stapleton, 2015). In this sense PBL is useful for both aspects.

Chan & Chen (2010) mention some problems that may occur in the implementation of this study methodology: poor communication, poor task management, unequal treatments among classmates; egocentricity; lack of responsibility and initiative. In the present study, one of the most important problems was the dropout of students. From an initial number of twelve students only seven finished the last phase. This high turnover, however, is frequent in assistant courses. Attendants are not paid, and, in many cases, they leave when they get a job opportunity. Communication was more difficult in the virtual stage of the course. A Facebook group was created

in order to improve the exchange and was friendlier than the Google classroom interface initially chosen. According to the observations of the teachers assigned to the course there were no egocentricity problems and the tasks were carried out by all the students equally. However, over time a natural division of tasks was produced: some students took charge of the design of the experience and others were mainly in charge of the practical work. Although it was not desired, the teachers in charge did not seek to alter this division of tasks, but they assure that all the topics that were discussed were learnt by the whole of the group. In PBL the teacher assumes the role of a mentor, providing resources, support and advice to students (Howard, 2002). In certain situations, in the design stages, teachers change their role to a co-researcher, being a peer member of the project group, and enhancing the intellectual conversations within (Thomas, Mergendoller, & Michaelson, 1999). The commitment of the teachers with the methodology is fundamental. They must not provide all the solutions without waiting for the opinion of the students, and when this opinion is expressed, it must be taken into consideration. The teachers must learn to intervene only when their contribution is necessary. The key to the critical thinking process is ensuring that students are appropriately challenged intellectually. A too complex question can create frustration, a sense of defeat, and ultimately abandonment of the task at hand (Laur, 2013).

As we found in this study, there is a common perception that bottled water is healthier and tastier than tap water (Saylor, Stalker Prokop, & Amberg, 2011). However, it has been shown that bottled water may be of lower quality than tap water, both from the chemical (Cidu, Frau, & Tore, 2011) and bacteriological point of view (Zamberlanda Silva et al., 2008). Moreover, the environmental effects of bottled water use are extensive (Gleick & Cooley, 2009). The educational task carried out at the sampling sites should also be highlighted. There were more than two hundred shops where the problem of nitrate contamination in water was patiently explained to the participants. Will this serve to change their habits of consumption or perception about bottled water? It has been said that environmental knowledge can drive environmental behaviour only if it arouses environmental emotions (Carmi, Arnon, & Orion, 2015). Feeling that you have been paying a high price for an equally contaminated water can trigger a strong emotion.

The experience carried out meets the criteria listed by Thomas that are presented in the introduction. The issue of water quality is central to the discipline and asking about the methodology for its control is undoubtedly a driving question. The students made a real experience,

built knowledge, although guided by teachers, but autonomously. Proof of the relevance of the results obtained is that they were admitted to be presented at an environmental health congress.

CONCLUSION

Critical thinking is undoubtedly one of the basic characteristics of science. The conclusion of a scientific experiment must be discussed in depth before it is accepted. But there are some differences between how science works and how it is taught. Also, in the so-called hard sciences, students often only receive processed information: Theories are explained, but not discussed (Golombeck, 2008). The guiding thread of the whole experience was to create a framework for students to discuss the path to follow at all stages, without providing an a priori response.

While many teachers agree that students need to experience the real world, replicating real world experiences within the classroom can be tricky (Laur, 2013). The experience that is described here belongs to the real world. Because of the time involved, it is impossible to implement in a common course, however the results obtained can be studied by other students, or even enriched with new results that can be obtained maintaining the original design. In fact, to date, the results obtained have already been presented in our public health courses, and we also plan to implement next year in the grade course a large-scale sampling of bottled water following the methodology developed in this experience.

Bruner, in his theory of the spiral curriculum raises deepening more and more the contents. As Bruner wrote, "Learning should not only take us somewhere; it should allow us later to go further more easily" (Howard, 2007). In a certain way, that is what was intended to do with the different courses, according to the type of students to whom they were directed. Not only deepening the contents, but also changing the strategies for others that allow a deeper analysis, such as case analysis, role playing or the realization of a project. This also allows to deepen the multidimensionality of the subject, incorporating more and more social content. In the new public health this can be a way to go further.

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