FEMS Microbiology Letters, 366, 2019, fnz143

doi: 10.1093/femsle/fnz143
Advance Access Publication Date: 1 July 2019
Research Letter

RESEARCH LETTER – Professional Development

Improvement of laboratory skills of Chemical and Civil Engineering students using an interdisciplinary service-learning project for water quality and supply assessment in low-income homes

María Natalia Piol[1,2], Andrea Saralegui[1], Gabriela Orero[3], Susana Boeykens[1], Silvana Basack[4] and Diana L. Vullo[2,4,*]

[1]Universidad de Buenos Aires, Facultad de Ingeniería, Laboratorio de Química de Sistemas Heterogéneos. Av. Paseo Colón 850, Buenos Aires, Argentina, [2]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Godoy Cruz 2290, Buenos Aires, Argentina, [3]Universidad de Buenos Aires, Facultad de Arquitectura, Cátedra de Patologías de la Construcción, Mantenimiento y Rehabilitación de Hábitat, Pabellón III, Ciudad Universitaria, Buenos Aires, Argentina and [4]Área Química, Instituto de Ciencias, Universidad Nacional de General Sarmiento, J.M. Gutiérrez 1150, Los Polvorines, Buenos Aires, Argentina

*Corresponding author: Área Química, Instituto de Ciencias, Universidad Nacional de General Sarmiento-CONICET, J.M. Gutiérrez 1150, (B1613GSX) Los Polvorines, Buenos Aires, Argentina. Tel: +54-11446-97542; Fax: +54-11446-97501; E-mail: dvullo@campus.ungs.edu.ar

One sentence summary: Chemical and Civil Engineering students learn water quality analysis in an innovative service-learning approach.

Editor: Beatrix Fahnert

ABSTRACT

The University of Buenos Aires (UBA) develops the UBANEX program, focused on service-learning projects for students involving social, environmental and public health concerns. One of the proposals was a collaborative project between UBA and the National University of General Sarmiento. Based on the hypothesis that students' voluntary involvement in social concerns improves their attitudes towards themselves and learning, the aim was to focus on the development of social and professional skills by implementing an interdisciplinary work for water quality and supply assessment in low-income homes from a southern district of the Buenos Aires Metropolitan Area. Eighteen volunteers—Chemical and Civil Engineering students—were recruited during August–December 2016. Tasks were distributed according to their interests: survey making, sampling, lab analysis, infrastructure checking, etc. Volunteers were surveyed in social involvement, lab skills, data compilation and analysis, leading to a final report with recommendations for a proper water use. The survey results compiled their feedback: 72% admitted an update on water quality problems, 60% learned new lab techniques and were able to analyze results, 89% supported the University's involvement in social concerns and 56% expanded their opinion about the professional field. The students confirmed their interest in participating in the next UBANEX project.

Keywords: service-learning; UBANEX; water quality; public health; social concerns

Received: 22 March 2019; **Accepted:** 25 June 2019

INTRODUCTION

UBANEX is a program focused on the development of service-learning projects for students of the University of Buenos Aires (UBA) involving social, environmental and public health concerns. One of these projects was titled 'Short-term action plan for the prevention of health risk from well water consumption', collaboratively presented by the Engineering and Architecture Faculties (UBA) and the Science Institute of the National University of General Sarmiento (UNGS).

Service-learning is an educational approach in which students apply what they have learned to a community service project (Webb 2016, 2017). One of the benefits of a service-learning approach is that students learn the importance of being involved in community service and volunteering and at the same time increase their knowledge about their future professional activity. Students that have participated in these programs have demonstrated significant gains in different areas such as attitude towards self, attitude towards learning, civic engagement, social skills and academic performance (Celio *et al.* 2011). Service-learning starts from the idea that mutual help is a mechanism of personal, economic and social progress that is better than the pursuit of individual gain (Furco 2011).

This paper describes the development and implementation of a service-learning project. This academic material constitutes a learning approach by practical application and reflective instruction. Based on the hypothesis that students' voluntary involvement in social concerns improves their attitudes towards themselves and learning, the aim was to focus on the development of social and professional skills by implementing an interdisciplinary work for water quality and supply assessment in low-income homes from a southern district of Buenos Aires Metropolitan Area (AMBA).

MATERIALS AND METHODS

Social concern: study area

The study area was selected based on a special request from the San Agustin neighborhood public kindergarten authorities (Fig. 1). In this area there are many low-income households shared between several families, with their own wells for the supply of untreated groundwater. San Agustín lacks sewerage facilities and has a high population density living in these underdeveloped conditions (~5000 inhabitants/km^2; ICO-UNGS 2014). In addition, the area is surrounded by the highly contaminated San Francisco and Las Piedras streams and crossed by an open storm drain receiving domiciliary discharges. As there are serious health problems related to water, mostly skin, digestive and respiratory diseases, the main focus of this work was on the evaluation of water quality, in the influence area of the kindergarten.

Work planification

Eighteen Chemical and Civil Engineering students were recruited as volunteers from August to December 2016. The volunteers had completed 20–80% of their studies. Each student collaborated according to their own interests under each specific professor supervision: survey making, sampling, chemical or microbiological analysis, infrastructure checking, etc., and attended meetings to be informed about key topics plus a final brainstorming meeting. These meetings were not structured as conventional lectures, but rather as informal talks to stimulate discussions (Fig. 2), ensuring high academic contents.

Water analysis

Twenty-five tap water samples were collected and immediately analyzed or kept refrigerated if necessary (APHA 2017). Physicochemical analysis consisted of color (APHA 2017), turbidity (APHA 2017) and NH_4^+ (APHA 2017) determinations by spectrophotometric methods; pH (APHA 2017) measured by potentiometric method; conductivity and conductimetric residue employing electrical conductivity methods (ISO 1985; APHA 2017); major anionic constituents such as chloride, nitrate, sulphate, fluoride, nitrite and total alkalinity as $CaCO_3$ by ion chromatography (APHA 2017); and the elements: iron, manganese, silicon, chromium, cadmium, arsenic, mercury, lead, calcium, magnesium, sodium, potassium and total hardness (calcium and magnesium) were determined by inductively coupled plasma method (US EPA 1994). The whole microbiological analysis of the 25 samples was carried out by three students, following the Argentinean Food Code recommendations (CAA 2012) including total coliform counts (Most Probable Number technique with Fluorocult-Brila Broth), total viable counts (Plate Count Agar), presence of *Pseudomonas aeruginosa* (Malachite Green Broth, Cetrimide Agar) and *Escherichia coli* (Readycult Coliforms 100) in 100 mL.

Student assessment and course feedback

The assessment consisted of a follow-up of each student performance in terms of aspects such as social involvement, development of chemistry and microbiology lab skills, and data compilation, and finally in the analysis of a final report and a survey. The survey consisted of questions covering different aspects of the whole project: (i) attendance at previous meetings; (ii) interest in the topic; (iii) previous knowledge about the social situation; (iv) opinions about the University's involvement in social concerns; (v) whether the project allowed learning new lab techniques; (vi) whether the project increased the interest in water contamination; (vii) whether the UBANEX project facilitated learning; and (viii) whether the project contributed to enlarging the sudent's view of the professional field. A parallel survey was performed with another group of 20 students belonging to the same careers and progress levels, but not included in this project. The main goal was to monitor the information they had about the water quality and its social consequences, together with their opinion about the involvement of the University in this issues.

RESULTS AND DISCUSSION

Working in the lab

Table 1 shows the compilation of the results of the analysis of the 25 water samples, together with the corresponding regulations (CAA 2012; Litter 2018; WHO 2018). Although most of parameters complied with the national legislation, nitrate, arsenic and microbiological determinations evidenced that the water quality could be considered as risky. These results were the topic of discussion among the students and professors, exchanging ideas to promote a better understanding of environmental concerns. The case of arsenic was one of these subjects, leading the students to explore national reports about the Argentinean situation (Litter 2018). In fact, this particular issue is controversial, since while the World Health Organization guide level is 10 μg L^{-1}, in the Argentinean Food Code (CAA 2012) it is 50 μg L^{-1}, which is still under discussion (Litter 2018). Another parameter that was over

Figure 1. Water supply conditions and location of San Agustín neighborhood, San Francisco Solano, Buenos Aires Metropolitan Area, the area of study.

the limit was nitrate, and it was concluded that this is particularly problematic taking in account the high infantile and pregnant populations of the study area. Microbiological analysis led to the conclusion that the quality of all the water samples was extremely low for drinking purposes. The students agreed that the presence of fluoride might be considered as either beneficial or prejudicial depending on the values. In this regard, all samples except one were under the recommended concentration range, but were not low enough to include fluoride as a dietary supplement. Extra monitoring of water fluoride concentration would be an action to take in future.

Student assessment and course feedback

Students evidenced high commitment in the different activities that they were assigned to. The sampling team knew exactly the correct way of collecting and storing the water samples, according to the different tests that needed to be carried out. The teams responsible for the physicochemical and microbiological analysis worked independently regarding the safety and biosafety laboratory guidelines. Illustrations of the enthusiasm and acquisition of abilities to carry out the assigned experimental work are shown in Fig. 3. The laboratory skills were spontaneously acquired and in an easier way than the traditional learning experiences. The students were able to develop their own criteria for the interpretation of the obtained results. The integration of the unfavorable results put them on alert about the water quality and its association with the social situation of the area of study.

When analyzing the surveys (Fig. 4), 72% of the students stated that their participation updated them on the water quality problem, 60% acquired new lab techniques and analyzed results, 89% supported the University's involvement in social concerns and 56% agreed that the project contributed to enlarging their own view of the professional field. One hundred percent of the students confirmed their interest in participating in the next UBANEX project: Development and implementation of water treatments for microbiological quality improvement and arsenic and nitrate removal. The survey performed with the non-UBANEX students provided evidence of the lack of knowledge both of the program and of the consequences of the low quality of AMBA groundwater. Some 75% expressed their intention of future involvement in new projects.

The UBANEX service-learning project improved students' attitudes towards learning and boosted their involvement in social concerns. They assayed analytical and microbiological techniques, organized information and participated in the preparation of the final report. This final report was delivered to the kindergarten authorities, and guidelines and recommendations were suggested to prevent health damage, highlighting the poor quality of the drinking water. Despite the microbiological contamination being possible to solve by heat treatment or even applying chlorine disinfection, the detected arsenic and nitrate levels restrict the water use to personal hygiene. The kindergarten children were instructed by the previously trained teachers, using didactic games to design flyers. The purpose of this was to encourage the children to distribute these flyers among their own families and neighbors as an awareness campaign

Figure 2. Team work meetings of the volunteers.

Figure 3. Working in the lab: physicochemical and microbiological analysis.

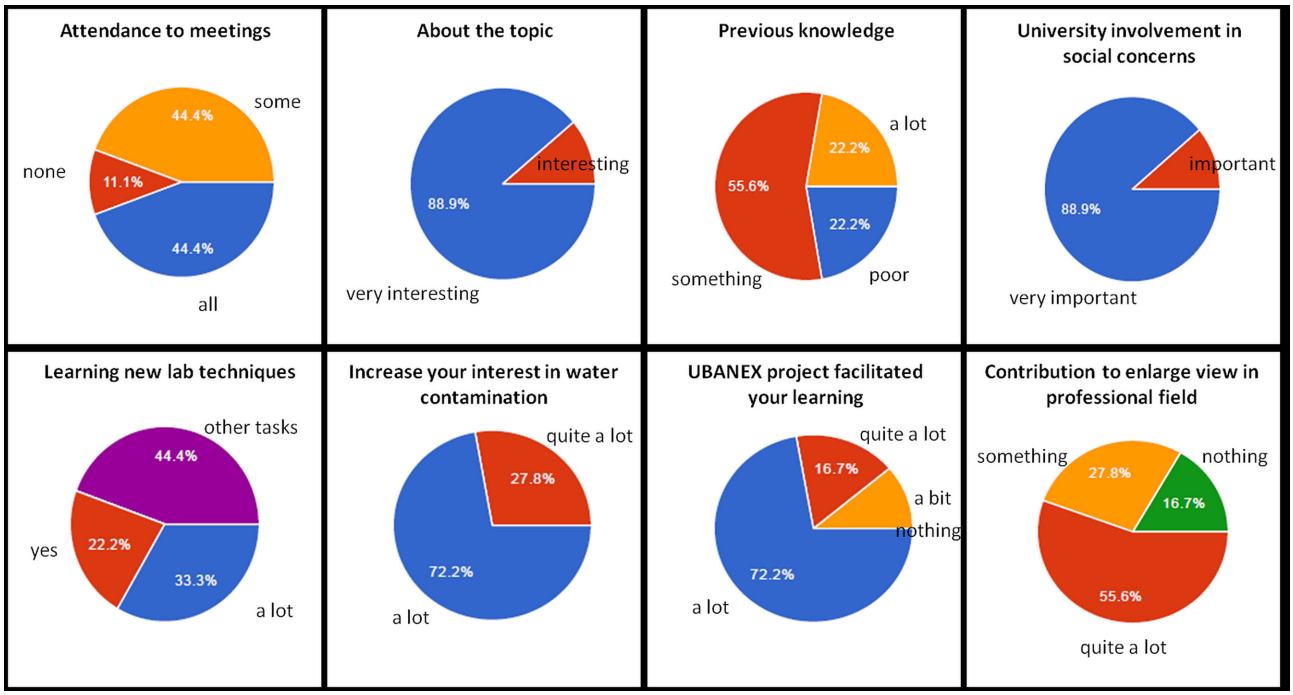

Figure 4. Results of the students' survey at the end of the work.

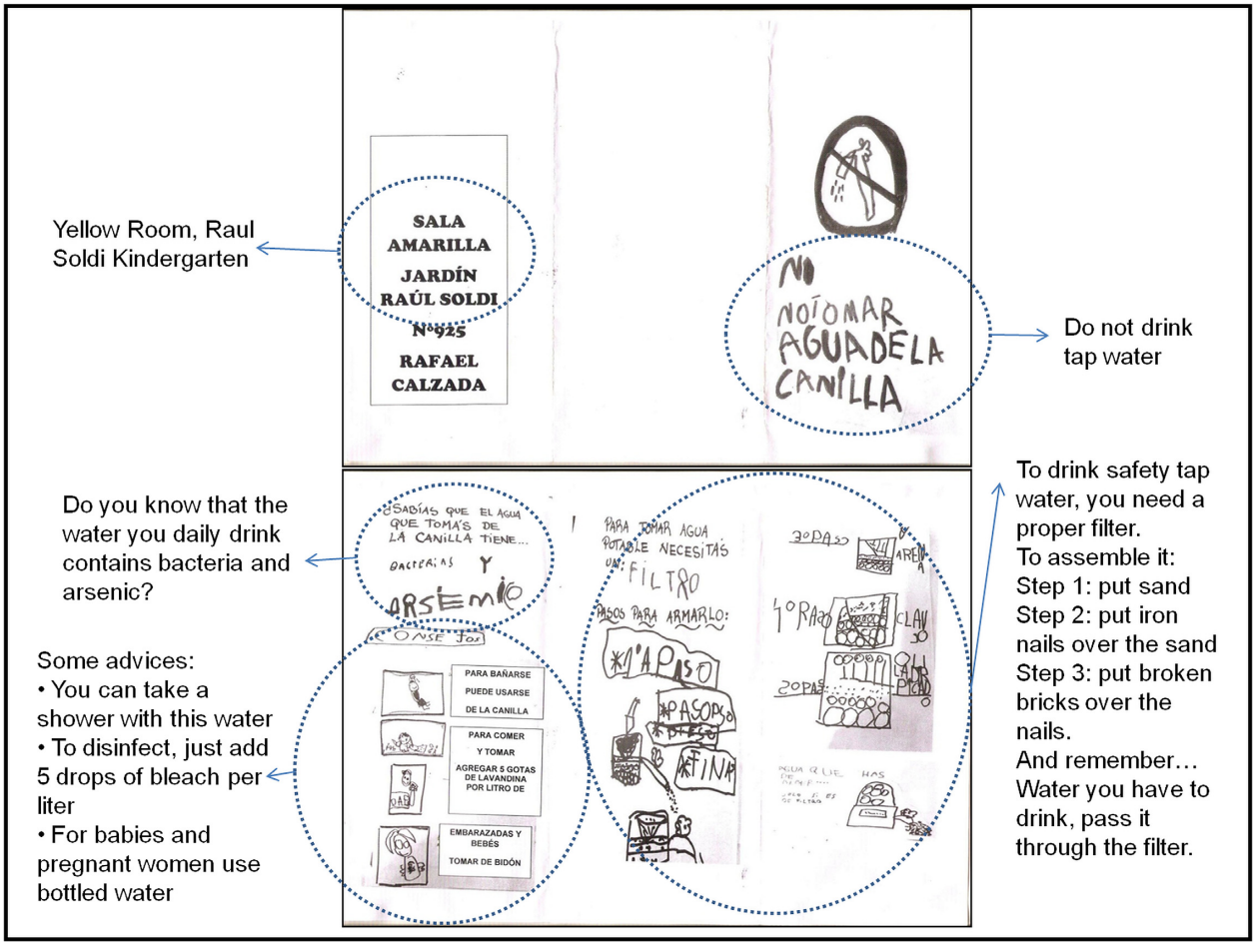

Figure 5. Flyer designed by the kindergarten children as an awareness campaign to prevent health problems.

Table 1. Physicochemical and microbiological analysis of water samples. CFU: colony-forming units; NTU: Nephelometric Turbidity Units; MPN: Most Probable Number.

Parameter	Result	Legal limits
Color	<5	≤5
Turbidity (NTU)	0.1–0.4	≤3
pH	7.00–7.90	6.5–8.5
Conductivity ($\mu S\ cm^{-1}$)	855–2270	No regulation
Conductimetric residue ($mg\ L^{-1}$)	577–1532	≤1500
Cl^- ($mg\ L^{-1}$)	15.6–180	≤350
NO_3^- ($mg\ L^{-1}$)	45.5–182, except 1 sample (24.0)	≤45
SO_4^{2-} ($mg\ L^{-1}$)	8.2–64.4	≤400
F^- ($mg\ L^{-1}$)	<0.5, except 1 sample (1.2)	0.8–1.3
NO_2^- ($mg\ L^{-1}$)	<0.01–0.09	≤0.1
$CaCO_3$ ($mg\ L^{-1}$)	420–801	No regulation
Fe ($mg\ L^{-1}$)	< 0.05, except 1 sample (0.74)	≤0.3
Mn ($mg\ L^{-1}$)	<0.04–0.08	≤0.1
Si ($mg\ L^{-1}$)	27–35	No regulation
Cr ($\mu g\ L^{-1}$)	<5	≤50
Cd ($\mu g\ L^{-1}$)	<0.1	≤5
As ($\mu g\ L^{-1}$)	10–37 Except 1 sample (9.3)	≤50
Hg ($\mu g\ L^{-1}$)	<0.5	≤1
Pb ($\mu g\ L^{-1}$)	<5	≤50
Ca ($mg\ L^{-1}$)	14–152	No regulation
Mg ($mg\ L^{-1}$)	18–46	No regulation
Na ($mg\ L^{-1}$)	146–310	No regulation
K ($mg\ L^{-1}$)	6.1–29	No regulation
Total hardness $CaCO_3$ ($mg\ L^{-1}$)	62–458	No regulation
NH_4^+ ($mg\ L^{-1}$)	<0.05	≤0.2
CFU mL^{-1}	>500, except 5 samples <370	<500
Total coliforms (MPN 100 mL^{-1})	>1100, except 4 samples <3.0	≤3.0
E. coli in 100 mL	+	Absence
P. aeruginosa in 100 mL	+	Absence

to prevent, and so decrease, the health problems detected in the population. An example of a flyer is shown in Fig. 5. This UBANEX project contributed to the improvement of health conditions of a small community thanks to the collaboration of Chemical Engineering students with a great commitment.

ACKNOWLEDGEMENTS

This work was supported by National University of General Sarmiento and Buenos Aires University- UBANEX 'Bicentenario de la Independencia'. We are grateful to Lic. Leticia Rossi for the English language revision.

Conflicts of interests. None declared.

REFERENCES

American Public Health Association, American Water Works Association and Water Environment Federation (APHA). Clesceri LS, Greenberg AE, Eaton AD (eds). *Standard Methods for the Examination of Water and Wastewater*, 22th edn. Baltimore, MD, USA: United Book Press, Inc., 2017.

Argentinean Food Code (CAA), Chapter XII. *Argentinean Law N°18284 and Joint Resolution SPReI N° 34/2012 - SAGyP N° 50/2012*, 2012. www.anmat.gov.ar/alimentos/codigoa/CAPITULO_XII.pdf

Celio CI, Durlak J, Dymnicki A. A Meta-analysis of the impact of service-learning on students. *J Exp Educ* 2011;**34**:164–81.

Furco A. Service-learning: a balanced approach to experiential education. *Int J Glob Dev Educ Res* 2011;**0**:71–6.

Instituto del Conurbano (ICO-UNGS). *Population Density of Buenos Aires Metropolitan Area (Map)*, 2014: http://observatorioconurbano.ungs.edu.ar/wp-content/uploads/099densida-poblacional10.pdf (5 June 2019, date last accessed).

International Organization for Standardization. *Water Quality – Determination of Electrical Conductivity* 1985, ISO 7888. https://www.iso.org/standard/14838.html

Litter M. Arsenic in water. *National Council of Scientific Research and Technology (CONICET) Final Report for Food Safety*, 2018:52-9. https://rsa.conicet.gov.ar/wp-content/uploads/2018/08/Informe-Arsenico-en-agua-RSA.pdf

US Environmental Protection Agency (US EPA). *Method 200.8 Determination of Trace Elements in Waters and Wastes by ICP-MS, Revision* 5.4. 1994: http://www.epa.gov/sam/pdfs/EPA-200.8.pdf.

World Health Organization (WHO). https://www.who.int/ipcs/assessment/public_health/arsenic/en/ (6 February 2018, date last accessed).

Webb G. Learning through teaching: a microbiology service-learning experience. *J Microbiol Biol Educ* 2016;**17**:86–9.

Webb G. A review of microbiology service learning. *FEMS Microbiol Lett* 2017;**364**:1-4.