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ORIGINAL RESEARCH

Chemistry tutoring sessions: educational support program for health sciences students

Monitorías en química: programa de acompañamiento para estudiantes de ciencias de la salud

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Abstract

Introduction: A high proportion of health sciences students at the Universidad Nacional de Colombia (UNAL) fail the basic chemistry (BC) course and, in some cases, this situation has caused them to lose their status as UNAL students.
Objective: To evaluate the efficacy of a tutoring program in reducing the percentage of health sciences students who fail the BC course at the UNAL.
Materials and methods: Holistic research carried out between 2011 and 2018, consisting of four levels and involving the participation of professors and students of the BC course, as well as professors and directors of the health sciences programs offered by the UNAL. At the perceptual level, the problem was described through the quantitative analysis of the academic reports of 1 983 students enrolled in the course from 2009 to 2011. At the apprehensive level, semi-structured interviews were conducted with 5 directors and 8 professors of the different health sciences programs, and a questionnaire was administered to 319 students to analyze the causes and possible solutions to the problem. At the comprehensive level, a tutoring program (designed according to the context-based learning approach), in which 3 050 students participated, was implemented. Finally, at the integrative level, the efficacy of the program was evaluated by comparing, through bivariate analyses, the academic results obtained in the BC course by the 4 545 students enrolled between 2011 and 2018 based on to their participation in the tutoring program.
Results: A significant difference in the course failure rate (p=0.000) was observed between students who participated in the tutoring program (18.73%) and those who did not (43.26%).
Conclusion: The implementation of the chemistry tutoring program allowed to reduce the failure rate of the BC course among health sciences students at the UNAL.

Resumen

Introducción. Una alta proporción de estudiantes de ciencias de la salud de la Universidad Nacional de Colombia (UNAL) reprueban la asignatura Química Básica (QB), y en algunos casos esta situación les ha hecho perder su calidad como estudiantes de la UNAL.
Objetivo. Evaluar la eficacia de un programa de monitorías para disminuir el porcentaje de estudiantes de ciencias de la salud que reprueban la asignatura QB en la UNAL.
Materiales y métodos. Investigación holística desarrollada en cuatro niveles entre 2011 y 2018 con la participación de profesores de QB y de estudiantes, docentes y directivos de los programas de ciencias de la salud de la UNAL. En el nivel perceptual se describió la problemática mediante el análisis cuantitativo de los reportes académicos de 1 983 estudiantes desde 2009 hasta 2011. En el nivel aprehensivo se realizaron entrevistas semiestructuradas a 5 directivos y 8 profesores de los diferentes programas de ciencias de la salud y se aplicó un cuestionario a 319 estudiantes para analizar las causas y posibles soluciones del problema. En el nivel comprensivo se implementó un programa de monitorías (diseñado con base en el enfoque de aprendizaje basado en el contexto) en el que participaron 3 050 estudiantes, y en el nivel integrativo se evaluó la efectividad del programa, al comparar, mediante análisis bivariados, los resultados académicos en la asignatura de los 4 545 estudiantes inscritos entre 2011 y 2018 de acuerdo con su participación en el programa de monitorías.
Resultados. Se observó una diferencia significativa en la tasa de pérdida de la asignatura (p=0.000) entre los estudiantes que asistieron a las monitorías (18.73%) y quienes no lo hicieron (43.26%).
Conclusión. La implementación del programa de monitorías en química permitió reducir la tasa de pérdida en la asignatura QB de los estudiantes de ciencias de la salud de la UNAL.

Introduction

Chemistry is a fundamental component of learning and practice in health sciences. However, it has been established that repetition and dropout rates in basic chemistry courses are high among students in the first years of exact sciences programs (including several programs in the health area),[1] thus becoming a barrier to enrollment into more advanced courses in their respective programs.[2]

This problem has been associated with the heterogeneous preparation of students in basic competencies during high school;[3] the intrinsic difficulty in understanding some abstract concepts of the discipline;[2,3] the limited applicability that students perceive of this knowledge in their professional practice;[3] the lack of integration between science, technology, and society;[4] teaching strategies based on extreme operativism;[5] the use of specialized language for teaching directed at non-chemistry students;[6] and the tendency of some universities to reduce laboratory practices and separate theoretical and practical courses.[7]

At the Universidad Nacional de Colombia (UNAL), the high failure rate historically recorded in the first years of introductory courses in basic sciences has been associated with the heterogeneous training of the students admitted and the entrenchment of the traditional teaching model at the institution, which is related to the poor pedagogical training of the professors.[8]

In 2007, an academic reform was approved at the UNAL which established that introductory courses in basic sciences would be offered to all students of similar academic programs without any differentiation and would be divided into theoretical and practical courses.[9] As a result of this reform, the theoretical Basic Chemistry (BC) course was created, among others, in which high dropout rates have been observed among health sciences students, especially in the first terms of their studies. This is also the case of the population that is admitted to the institution through the Special Admission Program (PAES, for its acronym in Spanish), which is aimed at high school graduates from indigenous communities; top high school graduates from poor municipalities; top high school graduates and students from the black, Afro-Colombian, *Palenquera*, and *Raizal* communities; victims of the armed conflict; and students from the Special Program for Admission and Academic Mobility (PEAMA), which is aimed at high school graduates from national border areas.[10]

Given that the repetition and desertion from this and any other course generates a great impact both for the students and the university, it is convenient to analyze the causes of the high failure rates and, with this diagnosis, propose and implement strategies that provide useful elements that contribute to the improvement of university education.

Thus, within the framework of the UNAL Student Support System,[11] an academic tutoring program was designed to provide counseling in the area of chemistry to health sciences students. These tutoring programs provide spaces for training and clarifying doubts, both for students and tutors,[12] which help to improve their learning outcomes.[13] Accordingly, the objective of the present study was to evaluate the efficacy of this tutoring program in reducing the percentage of health sciences students who fail the BC course at the UNAL.

Materials and methods

Study type

We conducted a holistic research, a type of study in which the problematic situation is understood as a system comprising the object of study and its relationships with the context.[14] This type of research is developed in levels, with integrated objectives conceived as sequential and simultaneous achievements that are reached in a continuous and systemic process based on the integration of quantitative and qualitative methods.[14]

This research was carried out between 2011 and 2018 with the participation of students, professors and directors of health sciences programs of the UNAL and was developed in 4 levels, each with a specific purpose: 1) perceptual level: quantitative description of the problem of high repetition of the BC course among health sciences students.; 2) apprehensive level: analysis of the causes and possible solutions to the problem; 3) comprehensive level: proposal of strategies to contribute to the solution to the problem; and 4) integrative level: evaluation of the efficacy of the implemented proposal.

Study population and sample

Taking into account the principles of holistic research, the study population and sample were determined in accordance with the specific purpose of each level.[15] Thus, the study population for the perceptual level consisted of the 1 983 students enrolled in the BC course from the first term of 2009 to the first term of 2011 (1 160 women and 823 men), who were distributed as follows: 577 (29. 10%) Nursing students (408 females, 169 males), 117 (5.90%) Physical Therapy students (91 females, 26 males), 663 (33.43%) Medical students (229 females, 434 males), 255 (12.86%) Nutrition and Dietetics students (214 females, 41 males), and 371 (18.71%) Dental students (218 females, 153 males). At this level, 100% of the population's data were used.

For the apprehensive level, the population consisted of 5 curriculum directors, 20 professors of the Department of Chemistry teaching the BC course, 23 professors of the Department of Physiological Sciences of the Faculty of Medicine, and 3 094 Nursing, Physical Therapy, Nutrition and Dietetics, Medical and Dental students enrolled from the first to the last year during the first semester of 2012.

Regarding the sample, all curricular directors participated in the study. In the case of BC professors, the sampling was incidental and 5 professors participated voluntarily; the sampling of professors of the Department of Physiological Sciences was discretionary and 3 professors of courses that require knowledge of chemistry (Biochemistry, Physiology, and Pharmacology) were interviewed. Finally, stratified sampling was used to obtain a sample of 319 students for the administration of a questionnaire, with a sex ratio of 1:1.3 and 1:1.7 (men:women) on the basis of their enrollment before and after the reform, respectively (Table 1).

Table 1. Population and sample of health sciences students included in the apprehensive level of the research.

Curricular program	Enrollment (in accordance with the 2007 reform)	Population			Sample		
		n	% Females	% Males	n	% Females	% Males
Nursing	Before	209	72.73	27.27	28	67.86	32.14
	After	439	69.70	30.30	47	78.72	21.28
Physical Therapy	Before	105	80.00	20.00	11	81.82	18.18
	After	115	72.17	27.83	15	73.33	26.67
Medicine	Before	675	38.81	61.19	24	29.17	70.83
	After	650	34.77	65.23	73	31.51	68.49
Nutrition and Dietetics	Before	94	85.11	14.89	8	100.00	0.00
	After	242	83.47	16.53	35	85.71	14.29
Dentistry	Before	233	63.09	36.91	31	70.97	29.03
	After	332	67.47	32.53	47	70.21	29.78
Total	Before	1 316	55.09	44.91	102	63.73	36.27
	After	1 778	58.55	41.45	217	61.75	38.25

Source: Own elaboration.

For the comprehensive and integrative levels, the study population consisted of 4 545 health sciences students enrolled in the BC course from the second term of 2011 to the second term of 2018. At the comprehensive level, the sampling was incidental and the sample consisted of 3 050 students (67.11% of the population) who voluntarily participated in the chemistry tutoring program, while the integrative level consisted of the entire population (Table 2).

Table 2. Population and sample of health sciences students included in the comprehensive and integrative levels in accordance with the academic program and type of admission to the Universidad Nacional de Colombia.

Group		Population (Comprehensive and integrative levels)			Sample (Comprehensive level)		
		n	% Females	% Males	n	% Females	% Males
Groups per academic program	Nursing	1 190	58.74	41.26	765	63.66	36.34
	Physical Therapy	310	54.84	45.16	88	64.77	35.23
	Medicine	1 676	38.42	61.58	1 463	39.51	60.49
	Nutrition and Dietetics	643	70.45	29.55	389	70.18	29.49
	Dentistry	726	55.79	44.21	345	58.26	41.74
Groups per type of admission	PAES	304	52.63	47.37	232	52.59	47.41
	PEAMA	159	67.30	32.70	18	83.33	16.67
	Regular undergraduate	4 082	51.54	48.46	2 800	52.11	47.89
Total		**4 545**	**52.17**	**47.83**	**3 050**	**52.33**	**47.67**

PAES: Special Admission Program; PEAMA: Special Admission and Academic Mobility Program.
Source: Own elaboration.

Procedures and instruments

Perceptual level

At this level, the problem was described by means of a quantitative analysis of the final grade obtained in the BC course by the 1 983 Nursing, Physical Therapy, Nutrition and Dietetics, Medicine, and Dentistry students who enrolled in this course from the first term of 2009 until the first term of 2011. The data, which were obtained from the database provided by the UNAL Academic Information System (SIA), were analyzed quantitatively considering the following variables: academic program, sex, type of admission, and alphabetical qualification (pass/fail).

Apprehensive level

At this level, which was carried out between 2011 and 2012, the causes of the problem and possible solutions were analyzed by conducting semi-structured interviews with 5 curriculum directors and 8 professors, and the administration of a questionnaire to 319 students.

The interview questions were designed based on categories. The questions asked to the directors addressed the categories 'importance of chemistry', 'BC course following the 2007 reform', 'causes of the problem', 'consequences of the problem', and 'possible solutions to the problem'. Professors of the BC course were asked about their appointment as professors of the course, the curriculum, the causes of the problem, the contextualization of the concepts, and their teaching training. Finally, the Biochemistry, Physiology and Pharmacology professors responded to the questions about the categories of 'students' training in chemistry', 'causes and consequences of the problem', 'necessary chemical concepts', and 'solutions'.

On the other hand, the student questionnaire, administered during the first term of 2012 to students who took the BC course before and after the reform, was designed *ad hoc* and consisted of 19 questions on learning experiences in chemistry, factors that positively or negatively impact learning, and the teaching resources used by the professors of this course (Annex 1).

Comprehensive level

Following the analysis of the previous level, at the comprehensive level, a chemistry tutoring program was implemented in which teaching strategies were proposed to promote learning. The tutoring sessions were guided by a chemistry professional who was also a master's student in Education at the UNAL with teaching experience, who designed the teaching strategies by integrating her disciplinary, teaching and technological knowledge of the contents. The tutoring sessions took place between the second term of 2011 and the second term of 2018 during the 16 weeks of the academic period and in 5 weekly sessions of 2 hours each. Participation was voluntary and attendance per session was recorded in a Microsoft Excel database.

Integrative level

At this level, the efficacy of the program was evaluated by comparing the passing rates of the BC course between those who did and did not participate in the tutoring sessions. The final grades of the participants were obtained from the SIA academic reports registered from the second term of 2011 to the second term of 2018. Data were presented in contingency tables using the following variables: academic program, type of admission, sex, and alphabetical rating (passed/failed).

Data analysis

Statistical analysis was performed using SPSS v.26. For the descriptive analysis of the data, absolute and relative frequencies (percentages) were calculated, and for the inferential analysis, bivariate analyses were performed using Pearson's chi-square test (X^2) in order to evaluate the differences in the academic results obtained in the BC course (passed/failed) between those who attended the tutoring sessions and those who did not, considering academic program, sex, and type of admission. A significance level of $p<0.05$ was considered. Qualitative information was analyzed with the Nvivo 2020 software through inductive and deductive categories.

Ethical considerations

During the research, respect for the dignity and protection of the rights and welfare of the participants prevailed. It was conducted under the principles of truthfulness, fidelity, reciprocity and respect for autonomy and was approved by the Ethics Committee of the Faculty of Medicine of the UNAL according to Evaluation Minutes No. 18 of October 27, 2011.

The administration of surveys and interviews was carried out with the authorization of the Faculties of Medicine, Dentistry, and Nursing. Likewise, the participants were asked to sign an informed consent form, preserving the confidentiality of their data at all times. The study followed the ethical principles for biomedical research involving human subjects established in the Declaration of Helsinki[16] and the scientific, technical and administrative norms for health research of Resolution 8430 of 1993 of the Colombian Ministry of Health.[17]

Results

Perceptual level of the research: quantitative description of the problems

Between the first term of 2009 and the first term of 2011, 1 983 health science students took the BC course: 1 559 (78.62%) took it only once; 328 (16.54%) took it twice; 82 (4.14%) took it 3 times; 12 (0.61%) took it 4 times; and 2 (0.10%) took it 5 times. 39.18% of the students did not pass the course and the highest percentage of failure was found among the special admission students (44.20%). The percentage of failure in the BC course according to the students' academic program is presented in Table 3.

Table 3. Results in the Basic Chemistry course of the health sciences students who took it between the first term of 2009 and the first term of 2011.

Program	Period	Passed (n)		Failed (n)		% of failure		
		Females	Males	Females	Males	Females	Males	Total
Nursing	2009-1T	13	6	47	13	78.33	68.42	75.95
	2009-2 T	47	11	45	15	48.91	57.69	50.85
	2010-1 T	53	22	53	16	50.00	42.11	47.92
	2010-2 T	48	25	36	25	42.86	50.00	45.52
	2011-1 T	29	14	37	22	56.06	61.11	57.84
	Total	190	78	218	91	**53.43**	**53.85**	**53.55**
Physical Therapy	2009-1 T	1	0	6	0	85.71	-	85.71
	2009-2 T	32	6	13	5	28.89	45.45	32.14
	2010-1 T	8	2	3	1	27.27	33.33	28.57
	2010-2 T	6	0	16	8	72.73	100.00	80.00
	2011-1 T	2	2	4	2	66.67	50.00	60.00
	Total	49	10	42	16	**46.15**	**61.54**	**49.57**
Medicine	2009-1 T	41	50	7	24	14.58	32.43	25.41
	2009-2 T	45	65	10	16	18.18	19.75	19.12
	2010-1 T	38	87	8	19	17.39	17.92	17.76
	2010-2 T	37	73	7	15	15.91	17.05	16.67
	2011-1 T	26	72	10	13	27.78	15.29	19.01
	Total	187	347	42	87	**18.34**	**20.05**	**19.46**
Nutrition and Dietetics	2009-1 T	23	6	11	2	32.35	25.00	30.95
	2009-2 T	16	4	23	2	58.97	33.33	55.56
	2010-1 T	22	7	24	1	52.17	12.50	46.30
	2010-2 T	39	6	16	2	29.09	25.00	28.57
	2011-1 T	24	3	16	8	40.00	72.73	47.06
	Total	124	26	90	15	**42.06**	**36.59**	**41.18**

Table 3. Results in the Basic Chemistry course of the health sciences students who took it between the first term of 2009 and the first term of 2011. (Continued)

Program	Period	Passed (n)		Failed (n)		% of failure		
		Females	Males	Females	Males	Females	Males	Total
Dentistry	2009-1 T	18	8	29	22	61.70	73.33	66.23
	2009-2 T	25	12	14	11	35.90	47.83	40.32
	2010-1 T	22	10	16	17	42.11	62.96	50.77
	2010-2 T	30	20	13	14	30.23	41.18	35.06
	2011-1 T	28	22	23	17	45.10	43.59	44.44
	Total	123	72	95	81	**43.58**	**52.94**	**47.44**
Health Sciences Total		673	533	487	290	**41.98**	**35.24**	**39.18**

T: term.
Source: Own elaboration.

Apprehensive level of the research: problem analysis

Semi-structured interviews with curriculum directors

The analysis of the causes and possible solutions to the problem, which was carried out based on the semi-structured interviews with the curriculum directors, is summarized in Table 4.

Table 4. Deductive categories and subcategories in the analysis of curriculum director interviews.

Category	Subcategory	Code
Importance of Chemistry	Contents	• Scientific pillar • Understanding of fundamental biological processes
	Curricular	• Prerequisite for other courses • Fundamental Area
Basic Chemistry course with the 2007 reform	Curriculum	• The needs of each program are not taken into account. • Inorganic chemistry is prioritized • Organic chemistry topics should be included in other courses. • Specificity is lost
	Problem	• High cancellation and failure rate
Causes of the problem	Students	• Poor foundations since secondary education • State of vulnerability/adaptation process to the university • Lack of motivation towards the curricular program
	Admission test	• Low admission scores • Poor science screening
	Contents of the course	• Difficulty with topics • They do not motivate students • Minimum contents that the professor of the course must guarantee to the students
	Professors	• Free teaching. Each professor deepens in the topics of their expertise • Inexperience. Lack of knowledge in pedagogy • Little interaction with the student • Autocratic relationship
	Teaching	• Inadequate methodologies • Single method, without taking specificities into account
	Logistics	• Large groups • Uncomfortable classrooms

Table 4. Deductive categories and subcategories in the analysis of curriculum director interviews. (Continued)

Category	Subcategory	Code
Consequences of the problem	For the university	• Vicious circle • Student backlog • Increased costs
	For the student	• Lack of motivation • Loss of student status • Delay in an academic terms • Delay in program completion
Possible solutions to the problem	Teaching	• Contextualization in chemistry and health • Extension of knowledge in pedagogy
	Curricular	• Content review • Leveling course • Immersion course • Change of course • Tutoring

Source: Own elaboration.

Semi-structured interviews to professors of the BC course

In the category 'appointment as a professor of the course', the interviewees stated that organic chemistry professors are appointed for this course, but it should be noted that one of them stated that "these courses are delegated to new professors or graduate students, when they should be given by professors with more experience and trajectory".

In the 'curriculum' category, participants stated that the content was initially too dense, so a decision was made to remove the topic of biomolecules. One of the interviewees stated that "the contents of the course are adequate, but perhaps the depth and mathematical focus of the topics are not, because they do not take into account what knowledge students of programs other than chemistry need".

In the category 'causes of the problem', the professors mentioned as the causes leading to most of the failure of the BC course the density and difficulty of the topics; the insufficient methods of study; the heterogeneous level of basic knowledge; the lack of interest in science; the adaptive and emotional problems of students entering the university; and the poor correlation between secondary education and higher education. One of the professors stated that she has been able to ensure that the failure rate in her courses was not a problem by "working on the chemical concepts from the ground up".

In the category 'contextualization of concepts', the interviewees agreed that when chemical concepts are framed in a context, students' interest is aroused; however, they acknowledged that since the 2007 reform it is more difficult to carry out this exercise.

In the 'teaching training' category, the participants agreed that the appropriation of knowledge is favored by the professors' disciplinary knowledge and the way in which they make the concepts explicit. Three of the interviewees stated that pedagogical preparation is reduced to the technique and means of communicating concepts and should not be mandatory for a scientist; one professor said that "disciplinary training is as important as pedagogical training", and another noted that "more important than pedagogical training is the vocation of being a teacher".

Semi-structured interviews with Biochemistry, Physiology and Pharmacology professors

In the category 'students' training in chemistry', one of the professors stated that it is "deficient" and others defined it as heterogeneous.

In the category 'causes and consequences of the problem', the professors agreed that the lack of contextualization linking chemistry and health is the cause of low performance and leads to disarticulation with posterior courses, which in turn leads to a fragmented training process.

In the 'necessary chemistry concepts' category, the interviewees emphasized that health sciences students need to understand the basic topics of general chemistry and organic chemistry, rather than their mathematical aspects.

Finally, in the 'solutions' category, the three professors agreed that it is necessary to bring chemistry into context of the interests of health sciences students and that professors should update their pedagogical knowledge.

Questionnaire administered to health sciences students (first to last year)

39.22% of the students who entered the university before the reform and 43.32% of those who entered after the reform stated that the chemistry training they received in high school was not useful for the BC course at the university.

The factors that positively impact learning were organized into 3 inductive categories: student-specific, professor-specific, and curriculum-specific. Thus, in the first one, 4 subcategories were identified: interest in chemistry (18.22%), autonomous learning (16.29%), previous concepts (13.84%), and study techniques (13.17%); in the second one, there were 5 subcategories: professor's explanation (37.03%), teaching tools (21.88%), contextualized exercises (11.31%), group work (7.20%), and evaluation (1.89%); and the third had 2 subcategories: laboratory practices (6.33%) and class schedule (4.15%).

The factors that negatively influence learning were organized into the same 3 inductive categories: student-specific, professor-specific and curriculum-specific, and subcategories also emerged from each of them. In the first, 2 subcategories were identified: lack of adaptation to the university (1.03%) and weak conceptual bases (12.71%); in the second, there were 4 subcategories: lack of clarity of the professor (28.78%), lack of contextualization of the topics (18.46%), lack of teaching resources (16.04%), and evaluation methodology (4.67%); and the third had 6 subcategories: thematic content (20.43%), high academic load (13.78%), schedule (9.11%), lack of tutoring (5.64%), inability to fulfill the academic schedule due to external circumstances (2.50%), and non-compliance with the curriculum (1.27%). 45.50% of the respondents stated that the influence of the chemistry professor in the university was positive and 40.00% stated that it was negative.

With respect to teaching tools, according to the participants, the use of molecular models and presentation projectors increased after the reform, but the use of demonstrative experiments, contextualized exercises and laboratory practices decreased.

The findings of the present study provide a deeper understanding of the causes that give rise to the problems analyzed here (Figure 1). It is noteworthy that, among the proposed solutions, curriculum directors, professors and students agreed on the importance of connecting the topics with the interests of the students.

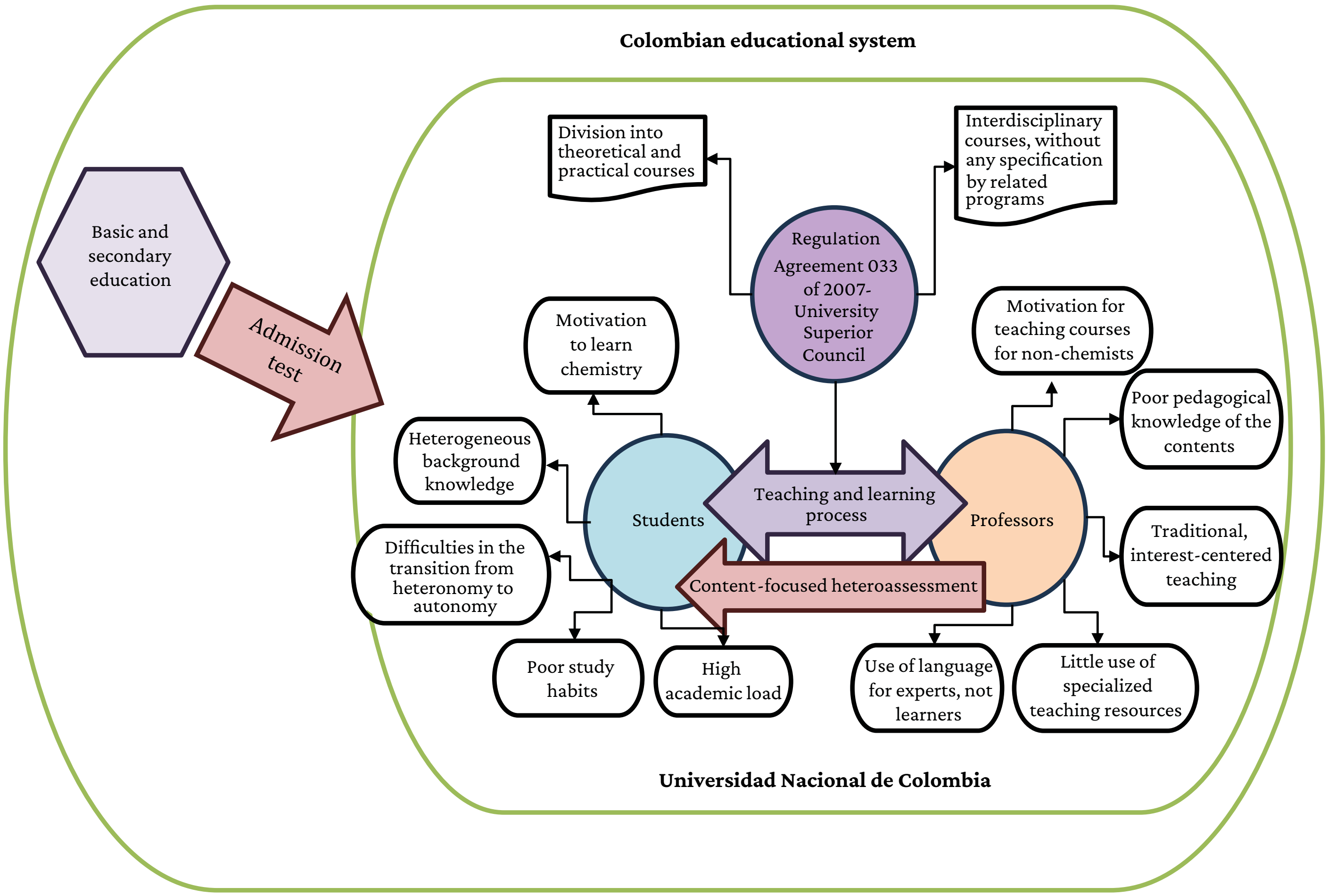

Figure 1. Causes of the problem.
Source: Own elaboration.

Comprehensive level of the research: proposed solution to the problem

Based on the results of the analysis obtained at the apprehensive level, a tutoring program was implemented using context-based learning (CBL), an approach that favors meaningful learning through the application of theoretical concepts in contexts or situations relevant to the students' interests.[18] Therefore, during the tutoring sessions, advice was given both on the basic topics learned at school and on the more advanced topics included in the BC syllabus, for which teaching resources such as molecular models, virtual laboratories and simulations were used. Similarly, a virtual classroom was created on the Moodle[19] platform to guide autonomous learning.

Medical students participated the most in the tutoring sessions and those who participated the least were Physical Therapy students. According to the type of admission, PAES students participated the most (Table 5).

Table 5. Participation of health sciences students in chemistry tutoring sessions between the second term of 2011 and the second term of 2018.

Group		Population n			Participants in the tutoring programs n (% participation)		
		Females	Males	Total	Females	Males	Total
Groups by academic program	Nursing	699	491	1190	487 (69.67)	278 (56.62)	765 (64.29)
	Physical Therapy	170	140	310	57 (33.53)	31 (22.14)	88 (28.39)
	Medicine	644	1032	1676	578 (89.75)	885 (85.76)	1 463 (87.29)
	Nutrition and Dietetics	453	190	643	273 (60.26)	116 (61.05)	389 (60.50)
	Dentistry	405	321	726	201 (49.63)	144 (44.86)	345 (47.52)
Groups by type of admission	PAES	160	144	304	122 (76.25)	110 (76.39)	232 (76.32)
	PEAMA	107	52	159	15 (14.02)	3 (5.77)	18 (11.32)
	Regular undergraduate	2 104	1 978	4 082	1 459 (69.34)	1 341 (67.80)	2 800 (68.59)
Total		2 371	2 174	4 545	1 596 (67.31)	1 454 (66.88)	3 050 (67.10)

PAES: Special Admission Program; PEAMA: Special Admission and Academic Mobility Program.
Source: Own elaboration.

The high participation of medical students is attributable to the fact that, as of 2014, the Faculty of Medicine approved the creation of a basic chemistry course taught by professors from the Department of Physiological Sciences and the tutoring sessions were included as part of this new course. On the other hand, the lower participation of Physical Therapy students is explained by the fact that the BC course is not mandatory in this program, and for PEAMA students, because many of them took the course before arriving at the Bogotá Campus.

Integrative level of research: evaluation of the proposed solution

Figure 2 shows that students who attended the tutoring sessions had a lower failure rate in the BC course than those who did not attend them.

Table 6 displays the results of the X^2 test, the significance (p) and the failure rate, discriminated by sex, for those who attended and did not attend the tutoring sessions by program and type of admission.

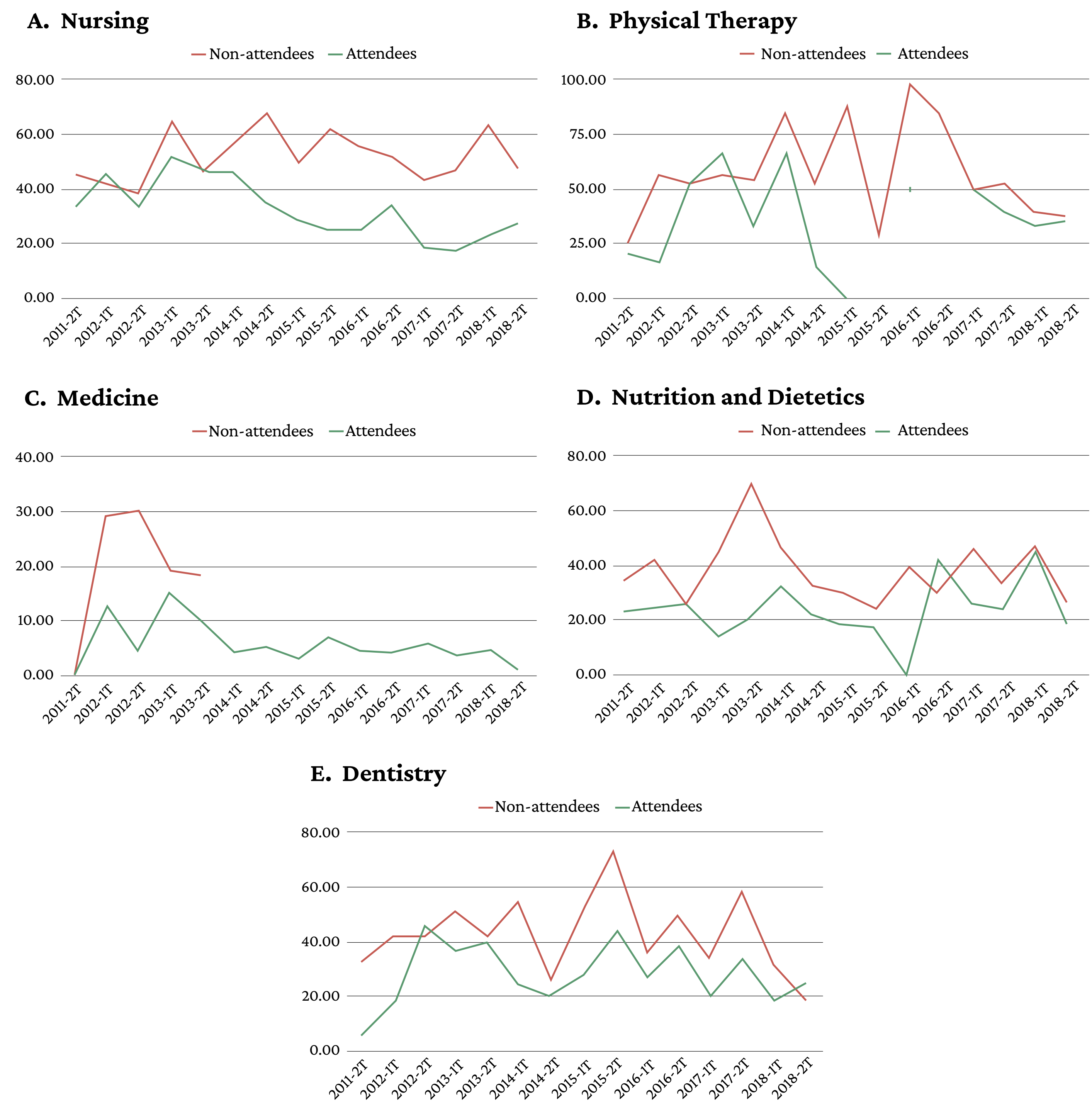

Figure 2. Failure rate of the Basic Chemistry course among health sciences students from the second term of 2011 to the second term of 2018. Source: Own elaboration.

Table 6. X^2 and *p*-value for the failure rate of the Basic Chemistry course among health sciences students based on attendance to tutoring sessions and sex by academic program and type of admission.

Groups		Result in the Basic Chemistry course	Attendance to tutoring sessions Females			Attendance to tutoring sessions Males			Attendance to tutoring sessions Total		
			Yes	No	X^2 *p*	Yes	No	X^2 *p*	Yes	No	X^2 *p*
Groups by academic program	Nursing	Passed (n)	390	232	36.55 0.000***	191	171	16.99 0.000***	581	403	58.09 0.000***
		Failed (n)	158	210		123	208		281	418	
		Failure rate	28.83	47.51	-	39.17	45.12	-	32.60	50.91	-
	Physical therapy	Passed (n)	45	94	6.17 0.013*	20	79	0.87 0.350	65	173	6.61 0.010*
		Failed (n)	23	99		14	79		37	178	
		Failure rate	33.82	51.30	-	41.18	50.00	-	36.27	50.71	-
	Medicine	Passed (n)	564	66	29.25 0.000***	861	141	63.08 0.000***	1425	207	95.46 0.000***
		Failed (n)	25	16		52	44		77	60	
		Failure rate	4.24	19.51	-	5.70	23.78	-	5.13	22.47	-
	Nutrition and Dietetics	Passed (n)	242	172	9.20 0.002**	102	58	7.59 0.006**	344	230	16.13 0.000***
		Failed (n)	74	92		32	40		106	132	
		Failure rate	23.42	34.85	-	41.18	50.00	-	23.56	36.46	-
	Dentistry	Passed (n)	174	204	7.69 0.006**	110	155	5.79 0.016*	284	359	14.94 0.000***
		Failed (n)	56	112		65	146		121	258	
		Failure rate	24.35	35.44	-	37.14	48.50	-	29.88	41.82	-
Groups by type of admission	PAES	Passed (n)	105	34	30.18 0.000***	104	32	26.94 0.000***	209	66	57.37 0.000***
		Failed (n)	29	48		12	26		41	74	
		Failure rate	21.64	41.46	-	10.34	44.83	-	16.40	52.86	-
	PEAMA	Passed (n)	10	79	8.49 0.004**	4	35	0.71 0.401	14	114	8.90 † 0.003**
		Failed (n)	22	53		5	24		27	77	
		Failure rate	68.75	40.15	-	55.56	40.68	-	65.85	40.31	-
	Regular admission	Passed (n)	1300	355	152.43 0.000***	1176	537	219.33 0.000***	2476	1192	368.45 0.000***
		Failed (n)	285	428		269	467		554	895	
		Failure rate	17.98	54.66	-	18.62	46.51	-	18.28	42.88	-
Total Failed (n) Failure rate		Passed (n)	1415	468	170.99 0.000***	1284	604	243.22 0.000***	2699	1372	408.36 0.000***
		Failed (n)	336	529		286	517		622	1046	
		Failure rate	19.19	40.79	-	18.22	46.12	-	18.73	43.26	-

PAES: Special Admission Program; PEAMA: Special Admission and Academic Mobility Program.
† For PEAMA students, the failure rate was higher among those who attended the tutoring sessions than among those who did not.
Statistically significant at *$p<0.05$, **$p<0.01$, ***$p<0.001$.
Note: This table takes into account all the times that each student has enrolled in the course.
Source: Own elaboration.

The differences in the failure rate of the BC course are statistically significant among students who attended and did not attend the tutoring sessions in all academic programs in both sexes, except for males in Physical Therapy ($p=0.35$), who had the lowest percentage of participation. Based on the type of admission, the tutoring sessions had a significant impact for PAES students ($p=0.000$) and regular admission students ($p=0.000$), but the failure rate for PEAMA students was higher among those who attended compared to those who did not, so the $p=0.003$ should be interpreted in the opposite direction to that of the other groups.

Discussion

Following the holistic research approach, the methodological design of this study combined qualitative and quantitative techniques in accordance with the objectives and the population and sample of each level of the study.[14]

The methodological moments of the research completed a holistic research cycle,[15] and based on the diagnosis and understanding of the problem, an alternative solution was proposed and its implementation reduced the failure rate in the BC course in a statistically significant manner.[20] This is of great importance because, according to Janssens *et al.*,[21] proposals for the transformation of problematic realities, such as the one addressed in the tutoring program evaluated, promote the development of education for sustainability, thus contributing to the improvement of the quality of higher education.

At the perceptual and apprehensive levels, it was found that the problematic situation is multicausal, so the results coincided with research that has established that the failure of basic chemistry courses is associated with causes related to the students,[1-3] the professors,[4-6] the educational institution,[7] and the contents.[1] In addition, this study had a distinctive element: the diagnosis of the problem covered the period before and after an academic reform, which made it possible to identify the effect of the change in the focus of the basic courses (which were separated into theoretical and practical courses and began to be offered without a specific focus on related programs) on the academic results of the students.

In this sense, it was found that after the reform, the number of students who consider that the knowledge of chemistry acquired in high school was not sufficient to understand the topics addressed in the BC course increased. This demonstrates that having weak conceptual foundations is a risk factor for failing because knowledge is built from basic concepts on which more complex concepts are anchored; therefore, the interrelation between preconceptions and new information is relevant to learning.[7] Thus, in the present study it was evidenced that when students are helped to obtain the basic knowledge of chemistry that they did not acquire in high school, as one of the chemistry professors interviewed does or as was done with the tutoring sessions, better academic results are achieved.

Following the 2007 academic reform, laboratory practices at the UNAL decreased because the BC course was transformed into a theoretical course, and the practical component, which is fundamental to understand the laws of chemistry, was eliminated.[7] To help professors who do not have the possibility of using the laboratory for their classes and to promote active learning, computational tools such as virtual laboratories and simulations have been developed;[22,23] however, the professors of the BC course did not use these resources and only used molecular models and video beam presentations instead.

Another important finding of the apprehensive level is that students recognize that the professor is a fundamental factor in both enhancing and discouraging their learning, which coincides with the findings of research that states that the professor's teaching methods and professional knowledge are very important for the achievement of significant learning.[24,25] However, the BC professors interviewed favor disciplinary knowledge over pedagogical knowledge and, as a consequence, traditional teaching methods in which the student plays a passive role prevail in the teaching of this course.

In order to design strategies that promote learning, professors must be aware of students' needs, interests, and difficulties.[26,27] In this sense, the professors participating in this study agreed on proposing, as the main solution to the problem, the contextualization of chemistry in relation to health sciences to improve motivation for learning.

According to Parolo *et al.*,[28] learning is enhanced when the concepts taught are articulated with the learner's interests, thus generating scenarios for metacognition. However, the BC professors interviewed admitted that the academic reform at the UNAL made it more difficult to focus on the needs of the students because it promoted the enrollment of students from different programs in the same class without any distinctions.

At the comprehensive level, the chemistry tutoring program based on the CBL approach was implemented because it favors interest and motivation for learning chemistry.[18,27,29] Moreover, teaching resources that, according to other research, facilitate the understanding of chemistry topics, were used in the lectures; these resources include molecular models,[30] virtual laboratories,[31,32] and simulations.[33] At this level, a virtual classroom was also created on the Moodle platform,[19] which is a tool with great potential for promoting autonomous learning in higher education.[34] Lastly, it was decided to change the disciplinary discourse of chemistry for a simple language during the tutoring sessions, since this helps the students to have better learning experiences.[6]

Consequently, at the integrative level, a significant difference was found (p=0.000) in the failure rate of the BC course between those who participated in the tutoring sessions (18.73%) and those who did not (43.26%). Furthermore, the lowest failure rate (5.13%) was found among medical students, who in turn had the highest participation rate (87.29%), since in this academic program, tutoring became an official component of the course. This proves that when educational support programs are articulated with academic activities, better results are achieved, as reported by Clerici & Da Re[13] in a study conducted at the University of Padua (Italy), in which they found that the program tutoring model can be an effective educational strategy, even in different contexts, by introducing the appropriate adjustments.

The positive results obtained by the students who attended the chemistry tutoring sessions in their performance in the BC course were favored by the teaching strategies designed by the tutor, in which she integrated her disciplinary, pedagogical, and technological knowledge. Thus, in line with recent research, the tutors not only provided students with strategies for learning, but also fostered their own learning and strengthened their teaching skills,[12] which contributed to reducing university dropout rates.[13]

As a limitation of the present study, it should be noted that in order to determine the efficacy of the tutoring program, only the six-month report on the number of students who passed and failed the BC course was available, being of interest for further studies to design and implement instruments that allow analyzing the perception of students who participate in this type of pedagogical interventions to reach conclusions that account for the complexity of the phenomenon under study.

Conclusions

The chemistry tutoring program, developed in accordance with the CBL approach, was effective in reducing the failure rate of the BC course among health sciences students at the UNAL. This higher pass rate of the students who attended the tutoring sessions demonstrated the need for the university to implement actions aimed at improving the teaching skills of professors of courses with high failure rates, as is the case of BC.

Note: Part of this research derives from the thesis developed to obtain the master's degree in education at the Universidad Nacional de Colombia entitled *Construcción de una propuesta pedagógica para el aprendizaje sustentable de la química en ciencias de la salud* (Construction of a pedagogical proposal for the sustainable learning of chemistry in health sciences),[35] authored by Soraya Elena Layton Jaramillo and directed by Ligia Inés Moncada Álvarez.

Conflicts of interest

None stated by the authors.

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Annex 1

Questionnaire administered to the participating students.

CONSTRUCCIÓN DE UNA PROPUESTA PEDAGÓGICA PARA FACILITAR EL APRENDIZAJE DE LA QUÍMICA EN CARRERAS DEL ÁREA DE LA SALUD

Student survey

This research is conducted by Soraya Elena Layton Jaramillo, a student of the master's degree in education and Higher Education at the Universidad Nacional de Colombia, Bogotá, and directed by Professor Ligia Inés Moncada. The objective of the study is to build a pedagogical proposal to facilitate the sustainable learning of chemistry in health sciences programs at the Universidad Nacional de Colombia, Bogotá Campus, so it is necessary to know the perceptions of the different actors involved in the teaching and learning process, whose participation is very important.

If you voluntarily agree to participate, you will be asked to answer the questions in this survey, which will take no more than 20 minutes. The information collected will be confidential, will be handled only by the researcher, and will not be used for any purpose other than research. Your responses will be coded using an identification number and will therefore be anonymous.

I agree to participate.
Signature ____________ ID Number ____________ Date ____________

Program ____________ Number of enrollments ____ Sex F ☐ M ☐

1. Are you enrolled in *Basic Chemistry* this term? Yes ☐ No ☐

2. How many times have you enrolled in chemistry during your undergraduate studies? ____________ times

3. How many credits did you enroll for the term you took chemistry? ____________ credits

4. Have you ever dropped chemistry when you enrolled in the course? Yes ☐ times ___ No ☐

5. List, from most important to least important, the reasons that led you to drop chemistry, if you have ever dropped it.

1. ____________
2. ____________
3. ____________
4. ____________
5. ____________

6. Do you think that the knowledge of chemistry you acquired in high school was useful for you to take on the chemistry course in the first term of university?	Yes ☐ No ☐
7. How many hours per week did you spend or do you spend on self-study of chemistry in the university?	________ hours
8. Did you receive support from chemistry tutors at the university?	Yes ☐ No ☐
9. If the answer to the above question was yes, where did you receive chemistry tutoring?	Department of Chemistry ☐ Your own faculty ☐
10. If you received chemistry tutoring, do you think it helped you to learn chemistry?	Yes ☐ No ☐
11. Did you receive help from outside the university to learn chemistry?	Yes ☐ No ☐

12. If the answer to the previous question was yes, what kind of external help have you received for the chemistry learning process?

____

____

____

13. Of the courses you have taken or currently take, for which ones have you needed or do you need knowledge of chemistry?

1. ________ **6.** ________
2. ________ **7.** ________
3. ________ **8.** ________
4. ________ **9.** ________
5. ________ **10.** ________

14. List the knowledge of chemistry (topics or concepts) that you have needed or currently need for other courses of your program.

1. ________ **7.** ________
2. ________ **8.** ________
3. ________ **9.** ________
4. ________ **10.** ________
5. ________ **11.** ________

6. ______________________ **12.** ______________________

15. List, from most to least important, the factors that **positively** influenced **your** learning of chemistry in the university.

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________

16. List, from most to least important, the factors that **negatively** influenced **your** learning of chemistry in the university.

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________

17. How did the chemistry professor(s) influence your learning of this topic at the university?

____
____
____

18. Of the following teaching tools, which were used by your chemistry professor(s)?

- O Lectures.
- O Acetate presentations.
- O Projector presentations.
- O Practical exercises.
- O Virtual laboratory.
- O Other. Which one? ______________________
- O Exercises related to your program.
- O Further reading.
- O Molecular models.
- O Demonstrative experiments.

19. Do you have any suggestions for improving the teaching and learning processes of chemistry at the university?

____
____
____

THANK YOU FOR PARTICIPATING IN THIS RESEARCH