Engineering students' attitude towards chemistry

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RESUMEN
Este estudio utilizó una metodología mixta —cuantitativa seguida por cualitativa— para explorar las actitudes de los estudiantes de ingeniería hacia la química (N=115). La primera fase utilizó un cuestionario para examinar las perspectivas de los estudiantes y sus compañeros acerca del curso de química, aspectos relevantes del curso y factores que contribuyen al nivel de dificultad del mismo. Contrario a los hallazgos de otros estudios, los resultados indicaron que la mayoría de los participantes posee una actitud neutral hacia la disciplina. La segunda fase utilizó entrevistas para explorar las razones de los estudiantes para tener una actitud determinada. Los participantes centraron su atención en factores que contribuyen al éxito o fracaso en el curso: tiempo, profesor, motivación, trimestre y horario.

Palabras clave: metodología mixta, química, actitudes, aprovechamiento, ingeniería

ABSTRACT

This study uses a mixed methods approach —quantitative followed by qualitative— to explore engineering students' attitudes towards chemistry (N=115). The first phase used a questionnaire to ascertain the perspectives of students and their peers about the chemistry course, course's relevant aspects, and factors contributing to course difficulty. Contrary to findings reported in other studies, results indicated that most participants had a neutral attitude towards the discipline. The second phase used interviews to explore students' reasons for having a particular attitude towards chemistry. Participants focused their attention on factors that contribute to their success or failure in the course: time, professor, motivation, academic term, and schedule.

Keywords: mixed methods, chemistry, attitudes, achievement, engineering

Introduction

This research studied the attitudes[1] toward chemistry of students enrolled in the engineering bachelor's degree programs at the Polytechnic University of Puerto Rico. The question that guided the study was: What factors contribute to the development of a particular attitude towards chemistry among engineering students? The idea for the study emerged from the body of literature that indicates that the attitude towards a discipline influences students' success in the course. Therefore, it is important for teachers to know students' attitudes toward the discipline they are teaching and the reasons for such attitudes.

A satisfactory grade in a class does not necessarily imply a positive attitude towards the subject, but according to behavioral psychology, good grades represent some reinforcement. Grades, diplomas, academic distinctions, and degrees are part of the positive or negative reinforcement students receive throughout their studies. If negative attitudes or believes are reinforced, those attitudes will influence students' performance (House, 1997) and their intention to enroll advanced courses within a discipline (Cavallo & Laubach, 2001; Dagelty & Coll, 2004).

In terms of chemistry, students' attitudes are influenced by their opinion, opinions of other people, media, previous experi-

1 An attitude is defined as the position one assumes when taking any action; that is, the probability to act in a certain way or the future response to a particular situation (Skinner, 1974).

ence, mathematical ability, professors, and course content. If students' attitudes toward chemistry are negative, they will need more assistance when studying for midterms and doing laboratory assignments (Berg, Bergendahl, Lundberg, & Tibell, 2003). Furthermore, if attitudes are negative, other activities related to the course will be negatively affected as well (Rudd, Greenbowe, & Hand, 2002). Students with a negative attitude tend not to grasp and learn chemistry concepts because these are not significant to them or they do not see a relationship between chemistry and their field.

Attitudes are not only related to student performance (Papanastasiou & Zembylas, 2004), but also to beliefs about their capacity to perform certain tasks, i.e., self-efficacy (Bandura, 1997). The way we interpret and respond to events is influenced by our beliefs about environmental and personal factors related to them. Those beliefs determine performance on academic tasks and the challenges the tasks represent in professional training. In chemistry, for example, students assess their self-efficacy according to what they know about their peers' experience, thus developing certain attitudes just on perception.

It is possible that students' attitudes regarding their mathematical ability and science self-efficacy are related with their chemistry self-efficacy. Bruning, Schraw, Norby, and Ronning (2004) stated that two students can receive the same low grade in a chemistry test, but the effects on their self-efficacy will be different. Nevertheless, the student with higher self-efficacy will probably stay in the course, as people with a strong self-efficacy focus on the demands of difficult situations to overcome obstacles (Bandura, 1986).

Behaviorist teaching approach

Since 1920, the educational process grounded its basis on behaviorism, rejecting innate knowledge, and making reinforcement the main tool for instruction. Teaching scientific concepts was based on the memorization of isolated facts, non pertinent information, and non integrated topic discussions. These practices generated negative attitudes toward science and were reinforced by parents who doubted their children's scientific self-efficacy and teachers who presented scientific concepts as difficult.

In Puerto Rico, although science programs were developed since 1931, an integrated approach was used, emphasizing "pure science". Scientific literacy was limited to the explanation of natural phenomena and reading about science. After 1940, curricula were revised and high school chemistry was taught using a behaviorist approach (Department of Education of Puerto Rico, 2003).

Behaviorist models have governed instructional design in the sciences for many years, proposing a detailed and sequential curriculum with a broad and technical content frame, and using standardized measures to assess learning. Behaviorism assumes that students do not have previous knowledge, thus changes in observable conduct are the only indicators of learning.

Pragmatist teaching approach

Pragmatism, which has its origins during scientific-related historical events such as the Copernican Revolution and the inventions of the 20th century, also explains human conduct as purely natural and not influenced by external or supernatural causes. As it is seen in behaviorism, pragmatism rejects innate knowledge, pointing out that true knowledge is obtained by using the scientific method. It reduces "what is true" to "what is useful", applying the scientific method to ordinary life problem solutions (Riestra, 1997). From the pragmatic viewpoint, truth resides on usefulness and success, thus all knowledge is considered useful if it is practical or instrumental for the attainment of something.

Pragmatic teachers see education as an active process and participate in the students' self-accomplishment, giving a practical sense to knowing. For this reason, pragmatic science teachers are critiqued because this model reduces the importance of scientific knowledge to an individual's particular need while forgetting the social benefits of the scientific activity. Hence, students and teachers decide if it is important to learn science for their professional development or if, on the contrary, it is better to learn only what will be useful. This position influences engineering students' attitudes, for their world view is pragmatic. Their undergraduate training prepares them to make decisions based on logical judgment, common sense, and the quest for practical solutions.

Research on attitudes

Studies relating students' attitudes toward chemistry and mathematical ability with academic performance in the chemistry class have been performed at the secondary level (House, 1995). In Israel, for example, the attitudes toward chemistry and physics of 300 eleventh and twelfth graders were surveyed (Hofstein *et al.*, 1977). Participants stated that chemistry is a less masculine discipline and less important than physics. In another study, 211 Israeli tenth graders were surveyed, finding no statistical difference between attitudes toward chemistry and mathematics. However, participants liked mathematics the most because they considered it more important and useful than chemistry (Menis, 1983).

A sample of students in a German post-secondary institution participated in a study about attitudes toward chemistry before formal instruction in the discipline. The results stated that gender is a significant factor that determines attitudes toward chemistry. Also, negative attitudes could be associated with low self-confidence levels and fear towards the course (Ziegler & Heller, 2000).

Other studies have assessed traditional achievement predictors in natural sciences, such as students' attitudes toward the discipline, traditional cosmologic world view, teachers' attitudes toward chemistry, and the understanding of the sciences (Aghadiuno, 1995). Based on this body of knowledge, Menis (1983) suggested that teachers need to invest time, energy and dedication in developing positive attitudes toward chemistry among their students, using different teaching approaches from those currently used at secondary and college levels.

Neerinck and Palmer (1981) studied Belgian freshmen's attitudes and expectations. They showed that freshmen have a negative attitude towards chemistry, which was reinforced by their perception of course difficulty. On the other hand, positive attitudes were supported by: professor's enthusiasm, professor's effectiveness in presenting course content, professor's knowledge, and experiences such as demonstrations or experiments (Bauer, 2002).

Thompson and Soyibo (2002) found a negative correlation between students' attitudes toward chemistry and content comprehension. In this study, the use of different teaching approaches in the chemistry class, such as lectures, demonstrations, discussions, and practical work, was fruitful in terms of academic performance and perception of the discipline among tenth graders. According to Ediger (1999), however, teachers have to struggle with students' attitudes as they represent an obstacle in understanding course objectives.

Research suggests that students do not have satisfactory academic achievement if they have negative attitudes towards the field, as it is in science and mathematics (Iben, 1991). For instance, researchers stated that Hispanic students dislike science and mathematics (Sorge, Newsom, & Hagerty, 2000) and this attitude represent a significant predictor of success (House, 1995; Reid & Skryabina, 2002). Furthermore, the influences of gender (Jones, Howe & Rua, 2000; Turmo, 2005), critical thinking skills (Brown, 1967), academic scenario, curricula, laboratory work (Okebukola, 1986), and perceived difficulty (Osborne *et al.*, 2003) in students' attitudes toward science have also been documented.

Methodology

This study combined quantitative and qualitative approaches.[2] The data collection strategy used in the first phase of the study was a questionnaire[3], which allowed the examination of the attitude towards chemistry of a large number of students. In the second phase, semi-structured interviews provided information regarding the reasons for the findings of the first phase.[4]

2 Mixed methods studies appear in the literature since 1930, and their benefits have been described by many authors (Creswell, 2002). Specifically, it has been stated that quantitative and qualitative approaches complement and enrich each other (Johnson & Onwuegbuzie, 2004).

3 Questionnaires effectiveness to measure students' attitudes towards science, technology, and mathematics (Deeds, Wood, Callen, & Allen, 1999; Francis & Greer, 1999) has been documented by various researchers in different educational settings (Bennett, Green, & White, 2001).

4 McMillan (2004) classifies this research design as explanatory because the purpose of the second phase is to explain the results of the first one.

The target population consisted of engineering students enrolled in the course Principles of College Chemistry (SCIE 1210) at the Polytechnic University of Puerto Rico during the 2007 spring trimester (March-May). All students, except those in the Environmental and Chemical Engineering programs, enroll in this course. Course sections are heterogeneous in composition having students from different engineering programs (civil, mechanical, electrical, computers, and industrial), land surveying, and computer science.

First phase: Quantitative

Questionnaire development. Fowler (2002), and Braverman and Slater (1996) guidelines were used during the development of the questionnaire. Four versions of this survey were developed: 1) based on the reviewed literature; 2) incorporating the evaluation of experts in the fields of research methods, chemistry, and writing; 3) incorporating the input from members of the population (i.e., cognitive interviews); and 4) incorporating the knowledge gain during the pilot study.

Cognitive interviews were carried out with five engineering students enrolled in the chemistry course, who volunteered to participate in the process of clarifying instructions, questions, alternatives, and vocabulary (Fowler, 2002). Participants evaluated all sections of the questionnaire: title, appearance, scope, number of pages, general and specific instructions, items, scale used to exert a response, and vocabulary. Information from these interviews pointed at the need to reorganize the questions into four sections: personal opinion, opinion of others, course relevant aspects, and aspects that contribute to course difficulty.

The course section assigned to one of the researchers was used for the pilot study. This section had 28 students enrolled, which meets McMillan's (2004) recommendation for the sample size of a pilot study (15 to 20 participants). The pilot study objectives were to determine the psychometric qualities of the questionnaire, evaluate any difficulties that may arise during its administration, students' understanding of instructions and items, and calculate the time it takes to answer the questionnaire.

Twenty-three males (82.1%) and 5 females (17.9%) participated in the pilot study. Participants' age ranged from 17 to 39 years, with a mode of 19 years (17.9% were 18, 50% were 19, and 17.9% were 20 years old). The majority were civil engineering students (32.1%) followed by electrical engineering (25%), and mechanical engineering (17.9%). Most of the students took classes during the daytime (82.1%). The majority of these students was taking college chemistry for the first time (89.3%) and had the minimum mathematics requirements (92.9%). Another characteristic was that 92.9% had taken chemistry in high school, of which 75% obtained an "A" or "B" grade.

Inspection of central tendency measures (median = 63, mean = 64), and skewness (-0.72) and kurtosis (0.72) coefficients for the scale used to measure the attitude (items 6 through 25) revealed that the distribution approached normality (standard deviation = 7.703).[5]

The Cronbach's alpha reliability coefficient was used to assess the internal consistency of the attitude scale because the items had multiple alternatives. This coefficient indicates how well a set of items measures a single unidimensional latent construct (UCLA: Academic Technology Services, Statistical Consulting Group, n.d.).[6] Since the interest was to differentiate among groups, a coefficient of 0.70 was considered appropriate (Crocker & Algina, 1986; Siegel & Castellan, 1988; Messick, 1989; Gronlund & Linn, 1990). The value obtained for Cronbach's alpha was 0.731. This coefficient met the criterion stated in the literature. Therefore, it was decided to use the questionnaire without making any changes. Furthermore, inspection of the behavior of Cronbach's alpha when a particular item is deleted did not increase the coefficient significantly. According to this analysis, the highest increment in the coefficient can be obtained when deleting item 24 (a .036 increase). A comparison of the two correlation coefficients (with and

5 According to Hinkle, Wiersma, and Jurs (1998), a distribution with skewness and kurtosis coefficients between -1 and +1 is approximately normal.

6 It is a good indicator of whether items measure the same thing (Nichols, 1999). The higher the coefficient, the stronger the case for a single latent structure unidimensional scale.

without item 24) using a Fisher Z-transformation revealed no significant differences between them (p = 0.772).[7]

It is important to mention that it was not possible to perform a factor analysis as another evidence of internal structure due to the small size of the target population. Gorsuch (1983) indicates that at least 10 subjects per item are necessary to perform a factor analysis. The attitude scale had 20 items, which requires at least 200 subjects to attain a stable solution.

The final version of the questionnaire contains 28 items divided into three pages. The first page has the title, general instructions (purpose, importance, and time it takes to complete the document), and demographic questions (gender, age, student classification, program, and number of mathematics courses approved). The second page provides specific instructions on how to answer the items related to students' attitude. The last page presents three questions related to whether the student took chemistry in high school, his or her final grade, and a question on how many times he or she has enrolled in the college chemistry course.

The rigorous steps followed during the construction of the questionnaire comply with the recommendations of experts (McMillan, 2004). Instructions were written as clear as possible, for the questionnaire is self-administered (i.e., the researcher is not present to clarify instructions). The questionnaire is not long, following research stating that there is an inverse relationship between the length of the questionnaire and the response rate (Fowler, 2002). In cases where the questionnaire is too long, participants may get tired and not answer all questions or may not answer to the best of their knowledge.[8]

Questions 1 through 5 and 26 through 28 are demographic in nature. Some authors in the survey field state that it is a good practice to present these questions at the end if their sole purpose is to describe participants, or at the beginning in case they are essential for answering research questions (Fowler, 2002; Braverman &

7 The Fisher Z-transformation test was used to assess whether the two correlation strengths were different (Institute of Phonetic Sciences, 1996).

8 Missing cases and answers that do not correspond with the participants experience present a potential bias to the study's results.

Slater, 1996). Since questions 1 through 5 provide information to answer specific research questions related to differences between groups of participants, they were placed first in the questionnaire. Another reason to place them first is that some researchers establish that demographic questions are a good way for participants to engage in the process of reading and answering questions because they are easy to read and to answer (Fowler, 2002).

Questions 6 through 25 collect information regarding students' attitude toward chemistry. Each question was answered using a Likert scale (Likert, 1932) ranging from *Totally Agree* to *Totally Disagree*. Half of the items are written in a positive way and the other half are stated negatively as recommended in the literature (Dhindsa & Chung, 2003). This is done to prevent participants from answering automatically without understanding or thinking about the meaning of the question.[9] Items 6 through 9, 13, 14, and 19 through 22 are stated in positive form. Items 10 through 12, 15 through 18, and 23 through 25 are stated negatively.

Items 6 through 14 collect students' opinion regarding chemistry as a science and as part of their profession in terms of its usefulness for their profession and other fields, as well as course difficulty. Items 15 and 16 provide data regarding students' perception of the opinion others have of the chemistry course. Items 17 through 22 deal with general aspects of the course (time, textbook, laboratories, content, and professor). Items 23 through 25 deal with reasons why engineering students may have difficulty with chemistry.

Items stated positively had a value ranging from 5 (Totally Agree) to 1 (Totally Disagree), while items stated negatively were coded 1 through 5. Responses were added obtaining a total score for each student. This total score was then used in the statistical analyses. The minimum possible score a student can obtain is 20 (negative attitude), while a maximum score is 100 (positive attitude). However, since the Likert scale does not intend to place items in a continuum regarding attitudes and

9 When automatic responses are exerted, incorrect generalizations may be formulated (Ray, 1982).

the scores within the extreme points are difficult to interpret (McIver & Carmines, 1981), the discussion, interpretation, and statistical analysis was limited to the results of the survey to then establish the criteria for comparisons.

Questionnaire administration. The questionnaire was administered at the beginning of the spring 2007 trimester. This period was selected so that course content and delivery did not pose a threat to the internal validity of the study, giving enough time for the enrollment process to finish. Courses at the Polytechnic University of Puerto Rico convene in two hour sessions twice a week for approximately 12 weeks.

The questionnaire was administered during the second week of classes, as part of the course activities. This ensured that the majority of the students answer the questionnaire, limited only by absences during the days it was administered. All students enrolled in SCIE 1210 were invited to participate in the study (N=115). Those who agree to participate were required to sign informed consent forms that explained the nature of the study, purpose, benefits, educational implications, and rights.

To avoid the inclusion of the instructor as an extraneous variable in the research, students were permitted to be alone in the classroom while completing the questionnaire. This also helped to ensure that the participant did not relate his or her course grade to the questionnaire results. Therefore, students could feel free to answer the questionnaire to the best of their knowledge. Once students completed the questionnaire, they placed them in a sealed envelope that one of the students handed to the researcher. After all students finished answering the survey, a list was provided so that those students interested in participating in the qualitative phase of the study could write their contact information.

Data analyses. The Statistical Package for the Social Sciences (SPSS) was used to perform the analyses. The data collected during the administration of the questionnaire was stratified according to gender, age, program, times the course has been taken, whether the course was taken in high school or not, the grade obtained in high school, and the amount of approved courses in mathematics. Frequencies and percentages were calculated for each particular response. Skewness and kurtosis coefficients were evaluated to assess normality, and the standardized score distribution was studied to identify outliers (Tabachnick & Fidell, 2007).

Statistical significance tests were performed to examine whether there were significant differences among groups. An independent samples t test was used for variables gender and whether or not the chemistry course was taken in high school. One-way Analysis of Variance (ANOVA) was used for variables age, classification, program, times the college chemistry course has been taken, final grade obtained in high school chemistry, and the number of approved mathematics courses. All statistical inference tests were evaluated using a .05 level of significance. The assumption of homogeneity of variance was examined using Levene's Test, while the required number of subjects per cell was evaluated using what the literature recommends (Tabachnick & Fidell, 2007), 10 subjects or more.

Second phase: Qualitative

This phase examined and documented the reasons for a particular opinion or belief, by promoting participants' reflection. Participants for the second phase of the study were among those students that completed the questionnaire and decided to collaborate voluntarily. Since the requirement to participate in the second phase was to have completed the questionnaire, it can be stated that the sampling strategy was a purposive sample. Three students participated from the interviews. Students were required to sign an informed consent form before the interview began. The specific research questions that guided this phase are presented in the Results section.

Interview process. Questions contained in the protocol were based originally in the literature review and then modified according to the results obtained through the questionnaire administration. The questions guided the reflective conversation and exchange of ideas between the participant and the researcher to obtain an in-depth description of students' attitudes and the reasons for a particular attitude toward chemistry. The researcher observed and noted all verbal and non verbal language, promoted reflection and conversation, clarifying both questions and responses, while trying to keep his ideas and beliefs out of the conversation to prevent bias. The interviews were documented through notes taken by the researcher during the process, recorded in audio to corroborate researcher's notes (Cangemi, 1972), and had a maximum duration of 70 minutes (Morgan, 1997; Mertens, 1998).

Data analysis. The data analysis started at the time of data collection. This is an important characteristic of qualitative methods, for it allows researchers to continuously examine the problem statement and research questions and make modifications when needed. This flexibility is important since it allows researchers to reach the root of a problem.

Interviews were transcribed *ad verbatim* to ensure that all statements stem from what was stated by the participants. These transcriptions were used to verify the notes taken during the interviews (e.g., verification of pauses, expressions of agreement or disagreement, and contradictions). Collected information was summarized, synthesized, and integrated in a coherent manner. Recurrent tendencies in the answers were extracted to establish the categories used in the analysis. Research questions were referenced during the entire process to organize the information and provide detailed evidence for each question.

Results

First phase: Quantitative

Questionnaire results revealed that the students' demographic background (See Table 1) was the following: 82.6% males (n=95) and 17.4% females (n=20); ages ranged from 17 to 43 years old (the mode was 19); 43.5% daytime students, 21.7% studied during the evening, and 33.9% had a mixed schedule.

The majority studied civil engineering (35.7%), followed by mechanical (20.9%), electrical (19.1%), industrial (14.8%), and computer engineering (9.6%). Most of the students were taking college chemistry for the first time (79.1%). From the 99 students (86.1%) who stated that they took chemistry in high school, 81.8% said they obtained an "A" or "B" grade.

Most participants (82.6%) had approved the mathematics courses required to take chemistry (basic math and pre-calculus). It is noteworthy that 8.7% of the students were taking a calculus course and 6.1% were taking differential equations. This sug-

Table 1

Demographic variables frequency table

Categories		*f*	*P*
Gender	Masculine	95	82.6
	Feminine	20	17.4
Age	17	1	0.9
	18	10	8.7
	19	33	28.7
	20	25	21.7
	21	11	9.6
	22	5	4.3
	23	5	4.3
	24	6	5.2
	25	4	3.5
	27 - 43	15	13.0
Classification	Daytime	50	43.5
	Evening	25	21.7
	Daytime/evening	39	33.9
	Special	1	0.9
Program	Civil	41	35.7
	Computer	11	9.6
	Electrical	22	19.1
	Industrial	17	14.8
	Mechanical	24	20.9
Math courses approved	Intermediate algebra	2	1.7
	Pre-calculus I	48	41.7
	Pre-calculus II	34	29.6
	Pre-calculus Compendium	11	9.6
	Calculus I	6	5.2
	Calculus II	4	3.5
	Calculus III	1	0.9
	Calculus IV	1	0.9
	Diff. Equations	7	6.1
Took chemistry in high school	Yes	99	86.1
	No	16	13.9
Chemistry high school grade	A	30	30.3
	B	51	51.5
	C	16	16.2
Times enrolled in chemistry	1	91	79.1
	2	10	8.7
	3	3	2.6

Notes. *N* = 115; percentages for chemistry high school grade were based on the number of students who reported that they took chemistry in high school.

gests that participants had the mathematics skills necessary in the chemistry course.

Only 99 students answered the questions related to the attitudes toward the chemistry course (items 6 through 25; Table 2 presents the percentages obtained for each item). Internal consistency was examined for the entire data set to enable a comparison with the results obtained in the pilot study. Cronbach's alpha was calculated observing an increase from the one obtained in the pilot study. The coefficient obtained in the pilot study was .731, while the coefficient obtained in the formal study was .817. According to Tabachnick and Fidell (2007), this increment is due to the increased number of participants.

Table 2

Attitude scale responses: Items 6 through 25

	TD	D	N	A	TA	Missing
Item 6	5.2	11.3	29.6	39.1	13.9	0.9
Item 7	2.6	6.1	26.1	42.6	20.9	1.7
Item 8	0.0	2.6	5.2	40.9	51.3	0.0
Item 9	3.5	8.7	32.2	38.3	14.8	2.6
Item 10*	33.0	25.2	29.6	5.2	5.2	1.7
Item 11*	33.0	22.6	22.6	10.4	10.4	0.9
Item 12*	2.6	8.7	40.9	30.4	16.5	0.9
Item 13	5.2	11.3	34.8	39.1	9.6	0.0
Item 14	15.7	20.0	37.4	20.9	6.1	0.0
Item 15*	0.0	4.3	21.7	44.3	28.7	0.9
Item 16*	36.5	14.8	28.7	10.4	9.6	0.0
Item 17*	0.0	0.9	12.2	47.0	38.3	1.7
Item 18*	9.6	16.5	43.5	20.9	9.6	0.0
Item 19	0.9	1.7	27.0	36.5	33.9	0.0
Item 20	13.0	24.3	42.6	13.0	6.1	0.9
Item 21	7.0	5.2	44.3	33.0	9.6	0.9
Item 22	3.5	6.1	59.1	23.5	3.5	4.3
Item 23*	5.2	17.4	52.2	19.1	4.3	1.7
Item 24*	4.3	11.3	54.8	18.3	9.6	1.7
Item 25*	4.3	13.0	36.5	32.2	13.0	0.9

Notes. n = 99; Items marked with an asterisk (*) were stated in negative form; TA = totally agree, A = agree, N = neutral, D = disagree, and TD = totally disagree.

An item deletion analysis was also performed with the survey results to compare with those obtained in the pilot study. The highest increment in Cronbach's alpha is obtained when Item 16 is eliminated (from .817 to .832, a difference of .015), not Item 24 like the pilot study suggested. Deleting Item 24 represents the next highest increment in Cronbach's alpha, from .817 to .826 (a difference of only .009). A comparison of the two correlation coefficients (with and without item 16) using a Fisher Z-transformation revealed no significant differences between them ($p = 0.745$). Once again, results do not point to the need for modifications.

What do engineering students think about the chemistry course in regards to the usefulness of chemistry in their profession, the usefulness of chemistry in other fields, and course difficulty? Engineering students' perspective regarding the usefulness of chemistry in their profession was assessed in items 6 through 8. The median for items 6 and 7, *chemistry is related to my area of study* and *chemistry will be useful in my profession*, was found to be between *Neutral* and *Agree*. On the other hand, the median for item 8, *every engineer must know chemistry*, lay between *Agree* and *Totally Agree*. Apparently, although students understand that it is relevant for engineers to know chemistry, they do not consider its relationship with their profession as very important.

Students' opinion regarding the usefulness of chemistry in other fields was found to be similar to the one found in items 6 and 7. The median lay between *Neutral* and *Agree*. This tendency may suggest that students may not have a clear understanding of their fields nor of the relationship of their fields with the chemistry discipline.

What students think in regards to the difficulty of the chemistry course varies in each item. Responses to items 10 and 11, *if I could eliminate one of my courses it will be chemistry* and *I am taking the chemistry course because I had no option*, were primarily distributed between *Disagree* and *Totally Disagree*. However, even when the attitude towards the need to take the course is positive, students agree in that it is a difficult course (Item 12), and were more neutral or disagree in regards to taking the basic course

(Item 13) and taking other chemistry courses later in their studies (Item 14).

What do engineering students think about their peers' opinion regarding chemistry? Students' perspective regarding the opinion of others towards the chemistry course is examined in items 15 and 16. Most students' think that others see chemistry as a difficult course (Item 15 showed high percentages between *Agree* and *Totally agree*.). However, in the item that stated that one must be insane to study chemistry (Item 16), the median was found between *Disagree* and *Totally disagree*.

What aspects of the course determine the attitude towards the discipline? Among the aspects of the course that can be seen as determinants of the attitude towards the discipline, time dedicated to the course (Item 17) and laboratories (Item 19) were found to be more important.

Items 18, 20, and 22-24 showed a tendency towards the *Neutral* category of the Likert scale. These items assessed students' perspective regarding the textbook, the professor, and the course content as factors that determine the attitude and that make the course difficult. In regards to whether topics related to their area of studies are presented in class (Item 21), participants responded between *Neutral* and *Agree*.

What other factors make the course difficult and influence their attitude? Items 23-25 showed a neutral attitude towards the content as a possible source of course difficulty. Since students' exposure to course content was minimal at the time the survey was administered, students may not have criteria to evaluate whether it can relate to their academic performance, and thus their neutral responses (Item 23 with 52.2% and Item 24 with 54.8% neutral responses). However, the median for Item 25 related to time as a reason for course difficulty lay between *Neutral* and *Agree*.

Are there any differences in attitude in terms of students' demographic information? One important assumption to consider in the analyses described in this section is the normality of the score distribution. According to Hinkle, Wiersma, and Jurs (1998), a distribution can be considered normal if all three measures of central tendency are similar (mean, median, and mode) and the skewness and kurtosis coefficients lie between +1 and -1.

The mean (63), the median (62), and the mode (60) coefficients obtained for the distribution were fairly close. The skewness coefficient was -.951. However, the kurtosis coefficient was 3.549. Normality, however, can be assumed with the aid of the Central Limit Theorem. According to this theorem, if the number of cases in the distribution is fairly high, one can assume that the distribution of sample means in the population is normally distributed even when the raw score distribution is not (Hinkle, Wiersma, & Jurs, 1998). Since the sample in this study had 99 complete cases, normality can be assumed.

Statistical differences were determined using the total score obtained by adding Items 6 through 25 as the dependent variable. Demographic variables constituted the independent variables. The assumption of homogeneity of variance was met for all tests except the One-way ANOVA performed with the Program in which students are enrolled (Levene's Test was $F[4, 94] = 2.789$, $p = .031$). No significant statistical differences were found in any of the analysis using an alpha of .05 as criterion. This result indicates that students' characteristics do not influence their attitude towards chemistry among students.

Second phase: Qualitative study

What factors are determinant in the attitude towards the course? According to students, factors that determine their attitude towards chemistry are: time dedicated to the course, professor, motivation, trimester, and time at which the course is offered. All participants expressed that the time dedicated to the course is extremely important for its successful completion. They expressed that obtaining a good grade in the course depends "definitely on me, how much time, dedication, motivation, and how much emphasis I put on the course". They mostly underscored their own effort as the main factor in answers such as "I understand that there is nothing difficult unless you do not have the disposition and dedicate time to it. It is not difficult, you just have to dedicate time to it", "and so my understanding is that for being successful, not only in the course but in everything in life, in my engineering career, I need to dedicate time". Another participant stated that the chemistry course requires more time than other courses: "I

Table 3.

Inferential statistics analyses results

Test	Independent variable	Degrees of freedom	Observed value	*p* value
Independent samples t test	**Gender** Male (*M*=62.30; *SD*=9.445) Female (*M*=63.44; *SD*=9.186)	26	.477	.637
	***Number of times that have taken college chemistry** One time (*n*=79; *M*=62.65; *SD*=9.854) More than once (*n*=11; *M*=60.64; *SD*=6.801)	88	.653	.515
	Chemistry high school Yes (*M*=62.56; *SD*=9.592) No (*M*=62.14; *SD*=8.132)	19	.175	.863
One-way ANOVA	***Age** 20 years or less (*n*=59; *M*=62.78; *SD*=9.407) 21-25 (*n*=28; *M*=62.32; *SD*=7.698) 26 or higher (*n*=12; *M*=61.58; *SD*=12.944)	2, 96	.087	.917
	Classification Daytime (*M*=63.27; *SD*=8.451) Evening (*M*=61.10; *SD*=11.122) Daytime/evening (*M*=62.00; *SD*=9.377)	2, 95	.423	.656
	***Highest math course approved** Pre-calculus (*n*=39; *M*=63.23; *SD*=8.966) Pre-calculus 2 (*n*=40; *M*=63.15; *SD*=9.697) Calculus or higher (*n*=18; *M*=59.06; *SD*=9.533)	2, 94	1.425	.246
	Program Civil (*M*=61.41; *SD*=8.889) Computer (*M*=56.20; *SD*=10.272) Electrical (*M*=64.90; *SD*=5.379) Industrial (*M*=62.65; *SD*=12.175) Mechanical (*M*=64.90; *SD*=9.188)	4, 94	1.975	.105
	High school chemistry grade A (*M*=65.85; *SD*=10.946) B (*M*=61.91; *SD*=8.981) C (*M*=58.93; *SD*=8.033)	2, 80	2.676	.075

Notes. * = categories had to be collapsed to comply with the number of cases per cell requirement. *n* = sample size; *M* = mean; *SD* = standard deviation. The sample sizes of those analyses that met the required cell size are presented in Table 2.

would say too much, too much time [...] one has to dedicate time to read, work on the exercises, understand everything, and then review it." These comments support the survey findings where 87% of the participants answered between *Totally Agree* and *Agree* to item 17: *The chemistry course requires lots of study time*.

The professor teaching the course was another factor that determines their attitudes. One of the participants talked about the differences between high school and college professors, stating the following:

> "High school chemistry teachers are not the best, they prefer to waste time or they write everything on the board, they fill the board and do not explain anything, that is, all you do is memorizing. They do not explain the reasons for things and, sadly, they make you lose motivation to study."

Another participant stated that the relationship between the professor and the student is a determinant factor in the successful completion of the course. The rapport established between the professor and the student facilitates the communication and the confidence to ask questions when one does not understand the content.

Motivation was not contemplated in the survey, but it emerged in the interviews. One student stated that "motivation is a factor that helps you", and another mentioned that motivation "is the base of everything". Experts agree in that motivation, either extrinsic (from family members, friends, and professors) or intrinsic (from the individuals' desire to reach a goal and the quest for improvement) exerts autonomy and control in the student, contributing to a better self-efficacy (Bruning, Schraw, Norby, & Ronning, 2004).

One student noted that the trimester in which the course is taken influences the final grade. The student provided her experience as evidence, being the second time she enrolled in the course. She failed the course the first time and mentioned, among other factors, that interruptions due to Thanksgiving and Christmas during the trimester running from November to February affected her academic performance: "Since you have a vacation break, the two weeks in December, one tends to not study for the course because it is time to be spent with family."

Another factor that emerged was the time at which classes are scheduled. It seems like new generations tend to avoid courses too early in the morning. The institution, however, offers most of the departments' specialization courses either early in the morning or late in the evening to cater to students that work either part-time or full-time. Natural sciences courses are mainly scheduled in the morning, being the preferred time at 7:00 a.m. One of the participants stated that her fear towards the course is due to taking the course at that time: "The class is so early in the morning that sometimes my brain is not working well." Thus, class schedule became one of the categories in the qualitative phase. Another student expressed that "getting up at 7:00 a.m. is not complicated for some people", but it was for her due to her work schedule.

What are their beliefs regarding the discipline? It is noteworthy that there was no consensus regarding the discipline of chemistry. Participants' ideas contradicted each other. One participant expressed that chemistry "helps us understand many things", another stated that "it is complicated and very interesting", a third participant said that it is a good foundation for the engineering career and for other courses, for example, physics. None of the participants presented ideas related to scientists' conceptions regarding chemistry: the science of matter, the study of its composition and structure.

What circumstances or reasons motivate engineering students to register in the chemistry course? What relationship do students see between their fields of study and chemistry? Regarding the circumstances that motivate engineering students to register in the chemistry course, participants agreed in that they need to take it "because it is part of the curriculum", or because they need it for their career. On the other hand, students do not find a relationship between chemistry and their field of specialization. This can explain why questionnaire items 6, 7, and 8, that deal with the usefulness of chemistry in the profession, showed higher response percentages in the *Neutral* and *Agree* categories. Apparently, students see chemistry as a subject that allows them to interact with other engineers, but not as an essential part of their professional development. Chemistry is seen as another engineering field, as one of the participants stated: "chemistry is in itself like an introduction… that introduction that helps you interact with other engineers that do not belong to your field". Commentaries suggest that chemistry is not relevant in terms of its contribution of content to their professional development, but as a tool that enables them to fit within the professional engineering community. Some commentaries were: "one never knows if you will end up working in a pharmaceutical company as an industrial engineer and it will not look good if one does not know what is being talked about". Participants do not have a clear understanding or do not perceive the curricular alignment between the contents of chemistry and engineering.

What aspects of the course catch their attention? Course aspects that caught participants' attention were topics related to nuclear chemistry, due to recent war developments, and the laboratories. Students think that chemistry is a more experimental science than physics. Also, they consider laboratories to be extremely important because they allow them to practice class concepts. According to students, it seems as if other scientific disciplines did not have the need to perform experiments. These expressions suggest that chemistry follows an empirical, practical and experimental didactic, while other sciences follow a more theoretical and mathematical approach. Such teaching styles can mislead students in the sense that chemistry, being more practical, can be seen as less complex than other sciences. But then, why do students think that physics is easier than chemistry?

What do their peers, friends, and family think about chemistry? How have they influenced their opinion? In regards to commentaries, beliefs, opinions or perspectives of students' peers, friends, and relatives about chemistry, one of the participants expressed a similar thought of what was conveyed in item 16 of the questionnaire (*People think that those who study chemistry are crazy*): "... is crazy, that is, you have to get involved in it, you cannot work [...] you have to dedicate the entire time, because there are so many things, so many details that you must consider in an exercise". On the other hand, another participant expressed that his peers have a somewhat positive attitude towards chemistry: "Some say it is easy, others that it is difficult. The majority is not here at the university, but those who are here say (with gestures and lowering his voice) that it is easy." These comments influence students' opinion, as one mentioned she was afraid of the course, not only because the class is more complex at the college level, but because the subject itself represents a challenge.

What are the reasons why engineering students have certain attitude towards chemistry? In regards to the central question that guided this part of the study, it can be said that students' attitudes are not determined by only one factor. Attitudes toward chemistry are influenced by multiple factors, which raises the complexity of the research problem. Interviews demonstrate why the survey responses median lay between 60 and 65. Engineering students do not have an attitude that tends more towards being positive nor negative toward chemistry. It is very personal and depends on their particular experiences with the course, especially in their way of understanding the relationship between the course and other courses, and their professional development. Moreover, our belief is that it should be examined whether students recognize the characteristics that distinguish engineering from the natural sciences and its different branches.

It was noteworthy that the participant from the electrical engineering program did not make any comments regarding the relationship between chemistry and the understanding of circuits, modern materials, electrical conductivity, the electrical field nature, the atomic structure, chemical bonding, bandwidth theory, corrosion, oxidation reactions and activity series. All these topics are part of the contents network of the course SCIE 1210, and they align perfectly with electrical engineering. Industrial processes, thermodynamics, kinetics, modern materials, stoichiometry, environmental chemistry and the balances of matter and energy in a production system are topics related to industrial engineering, especially with the pharmaceutical industry, and students from this program did not mention any of them. If a student does not understand that chemistry is closely related to his or her field in all these aspects, then it is possible that the student does not have an in-depth understanding of his or her own field of study.

Half of the population that was surveyed (50.4%) was 19 or 20 years old, which means that they are probably in their second year of college. Students at this level have not yet started to take courses in their respective programs. Therefore, since they do not know the field, both parts of this research, quantitative and qualitative, suggest that participants cannot establish a relationship between chemistry and its utility in the engineering profession and other fields.

Discussion

The quantitative approach revealed that students have an attitude between neutral and positive regarding the pertinence of chemistry to their profession and a neutral attitude towards the pertinence of chemistry to other fields. It can be hypothesized that this attitude is due to the students' profile. The majority were 19 years old freshmen or sophomores, thus they are new to the engineering field.

Participants have a neutral attitude on items related to course difficulty, even though the idea of chemistry as a complicated discipline is maintained. Perspective on their peers' opinion about chemistry is negative in comparison with other questionnaire items or with interviews in the qualitative phase. The opinions of relatives and friends represent an attitudinal reinforcement for students' opinion.

T tests and ANOVAs results revealed no statistically significant differences among engineering students' attitudes according to: gender, age, programs, classification, mathematical ability (approved courses), whether or not a chemistry course was taken in high school, high school chemistry grade, and times the course has been taken in college. The reason for these results seems to be due to the tendency for a neutral response and the moment during the term students were surveyed.

The qualitative approach helped to gain insight on questionnaire results. Interviewees focused their attention not on their attitudes per se, but on factors that can facilitate their success in the course. They stated that the time allotted to study for the course, professor, personal motivation, academic term, and course schedule are determinant factors for course success. Students agreed on these aspects, emphasizing that time allotted to study for the course is very important to obtain satisfactory grades. Other factors included teaching strategies and methods used by professors. According to students, chemistry is a practical field, where applied exercises are needed to grasp concepts and problem solving mechanisms. The ways concepts are presented in lectures, compared to test questions, affect students' performance and cause them to develop negative attitudes. On the other hand, students understand that their own commitment with undergraduate training is a determinant factor in their final grades.

Students' beliefs about chemistry are contradictory. They consider that chemistry is important in their field, but they are not able to establish relationships between chemistry concepts and their profession. Interviewees cannot explain the way scientific knowledge derived from chemistry can help them as engineers. This can be explained by the fact that engineering students take chemistry in their freshmen year just to complete base core credits. Participants then have a neutral position when asked if they will take advanced chemistry courses before graduating.

Class content did not receive participants' attention, except the nuclear chemistry concept. Factors related to course success and, therefore, to attitudes toward chemistry were mathematical ability and self-efficacy, units' conversion problems, laboratory experiences, and time allotted to study for the course.

Comments, beliefs, opinions, and perspectives of relatives, friends, and colleagues influence participants' attitude. Sometimes, those beliefs act as an attitude reinforcement, which is then expressed when deciding for a profession, explaining the relationship between engineering and chemistry, and in the way they face course content. Participants stated clearly that attitudes are diverse among their colleagues, but the tendency is to believe that "chemistry is a very hard science". Therefore, peers, relatives, and friends influence their attitude towards chemistry.

Suggestions for future studies

Future studies should include students at different stages during their college years to examine how attitudes change over time. Students are required to take different courses, taught by different professors, using different strategies, and at different academic terms. This will enable a comparison among groups to determine tendencies or changes in attitude. The first part of the study can be a questionnaire. For the second phase, a qualitative study using focus groups is recommended. Different focus groups can be performed representing all population subgroups.

Studies like the one described can be replicated in other scenarios (e.g., private versus public institutions), contributing to the generalization of findings. Others can examine the students' perspectives in other disciplines (e.g., natural sciences, education). The latter will help to examine differences among students in diverse fields.

In order to transform higher education in today's knowledge-based society, it is imperative to deal with students' attitudes when teaching the principles of scientific literacy needed to excel in a world of technological advances, multiple challenges, and new paradigms. Studies are needed to support previous and future research on attitudes so that the generalized belief in the future can be: "everybody should learn chemistry" (Nakhleh, Bunce, & Schwartz, 1995).

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