SCIENTIFIC VOCABULARY AS A MEASURE OF EVALUATION OF THE KNOWLEDGE OF HIGHER-LEVEL STUDENTS IN SPECTROSCOPIC TECHNIQUES

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ABSTRACT

Knowledge of academic-scientific vocabulary in any field of study differentiates well-prepared university students from those with academic deficiencies. When analyzing the various elements that contribute to adequate scientific training of future chemistry professionals, it seems undoubted that the acquisition and correct use of basic academic-scientific language represents a transcendental factor in their professional success. The aim of this contribution is to evaluate the impact of learning specialized academic vocabulary in the students that attend a spectroscopic class, that is, vocabulary that belongs to a specific area or field of knowledge, on spectroscopic techniquesIt important to note that the aim and the scope of this contribution it doesn't consider the emotional or cognitive aspects of learning of specialized academic-scientific vocabulary. In this sense a methodological proposal is presented to evaluate in a practical, efficient and reliable way the acquisition of specialized academic-scientific vocabulary in a group of university students. With the results generated, it is proposed that certain activities be carried out through collaborative work by the students, to facilitate the learning and understanding of the academic scientific terms associated with the techniques of UV-Vis, IR, MS and NMR. Likewise, it is proposed to implement specific activities that reinforce the vocabulary of the UV-Vis technique. The findings of the study revealed not show a significant statistical difference regarding the management of scientific vocabulary between both genders.

KEYWORDS

Scientific Vocabulary, Spectroscopy, Collaborative Work, Gender, Undergraduate Students

1. INTRODUCTION

Knowledge of academic-scientific vocabulary in any field of study differentiates well-prepared university students from those with academic deficiencies [1]. Various studies have been published dedicated to the study of basic scientific vocabulary that students must know to perform successfully in the university and professional environment.

In the same vein, other researchers have dedicated themselves to the study of academic vocabulary by specific disciplines, in Computational Sciences [2]; [3], in Engineering [4], in Medicine [5]; [6]; [7] and in Agriculture [8] among others, arguing that there are individual features associated with the vocabulary that identifies each area or subarea of knowledge.

When analyzing the various elements that contribute to adequate scientific training of future chemistry professionals [9], it seems unquestionable that the acquisition and correct use of basic academic-scientific language represents a transcendental factor in their professional success [10]; [11]; [12];[13]; [14]. The use of scientific language is a decisive domain to be able to access the study of any science, in the specific case of the spectroscopic techniques used in the structural characterization of molecules, given the great variety of types of spectroscopic techniques that are available. That is why the lack of knowledge of scientific language can become an obstacle that hinders the process of teaching and learning spectroscopic techniques such as ultraviolet-visible absorption spectrophotometry (UV-Vis), infrared absorption spectroscopy (IR), mass spectrometry (MS) and nuclear magnetic resonance (NMR) that are usually studied at the undergraduate and graduate levels.The work aims to study specialized academic vocabulary, that is, the vocabulary that belongs to a specific area or field of knowledge, on spectroscopic techniques. In this regard, a methodological proposal is presented to evaluate in a practical, efficient and reliable way the acquisition of the academic-scientific vocabulary specialized in the techniques of UV-Vis, IR, MS and NMR in a group of university students of the seventh semester of the degree in Industrial Chemistry of the FES Cuautitlán UNAM (Mexico).

For the purposes of this research we will establish that vocabulary is composed of words, which are the basic lexical units of meaning [15]. In other words, the proposed methodology evaluates independent and isolated words from a context. It was decided to adopt this definition of vocabulary due to the format of the language assessment instrument that was developed and applied in the research, which consists of a lexical decision test in the format of a checklist. These tests measure receptive knowledge of vocabulary through a recognition task. The use of vocabulary assessments allows valuable information to be obtained about students' lexical knowledge. Enabling teachers to plan pedagogical activities appropriately [16]; [17] on a topic. Vocabulary assessments usually contain standards, to compare a student's vocabulary level with that of their peers. This information allows the development of pedagogical interventions for those students who have an insufficient level of vocabulary to face comprehension or writing tasks.To know a word is to understand its meanings [18]; [19]. They distinguish three dimensions: amplitude, which refers to the size of the mental lexicon, that is, the number of words that an individual handles; depth, which refers to the richness of meaning; and access lucidity, which is defined as the speed with which the individual accesses the meaning of the word.

In order to improve the scientific training of the students of the bachelor’s degree in industrial chemistry of the FES Cuautitlán UNAM, it is proposed to carry out certain activities through collaborative work by the students, in order to facilitate the learning and understanding of the scientific academic terms associated with UV-Vis techniques, IR, MS and NMR**.**

2. METHODOLOGY

For the evaluation of knowledge of the techniques of ultraviolet-visible absorption spectrophotometry, infrared absorption spectroscopy, mass spectrometry and nuclear magnetic resonance, the degree of management of the academic-scientific vocabulary that must be used in each technique in a specific way was determined. A group of students enrolled in the seventh semester of the bachelor’s degree in industrial chemistry participated in this evaluation, which was made up of a total of 45 students, 21 female and 24 males, with an average age of 21 years. All the students who participated had studied the subject of spectroscopy for four hours a week for 16 weeks distributed as follows: UV-Vis (8 hours), IR (18 hours), MS (18 hours) and NMR (15 hours). At the beginning of the semester and in order to evaluate the degree of vocabulary management of each of the spectroscopic techniques that would be studied, an evaluation called Pretest was applied in person, where a total of twelve questions were handled (Annex 1). The classes were taught using contents of each spectroscopic technique developed electronically in

Power Point, complementing the didactic strategy with the individual interpretation of spectrograms of each technique, in addition to using collaborative work, the analysis of scientific articles related to the technique studied at that time was promoted. In addition to additional exercises, they were sent for resolution outside the classroom. The same didactic strategy was used for the study of the four spectroscopic techniques considered. Likewise, the student was asked to carry out a final project where he integrated the four spectroscopic techniques reviewed for the identification of a problem compound assigned by the teacher. Two examinations were performed, the first of which included the UV-Vis and IR techniques and the second considered the joint evaluation of the four spectroscopic techniques. At the end of the course, an exam called Posttest was applied again in person, where questions one and two were no longer considered.In both exams, students gave their consent for their results to be used for statistical and educational research purposes. In the format of the Pretest and Posttest evaluation, it was considered in question one to know if the student is the first time taking this subject and in question two it was applied to know if the student had any previous knowledge of the techniques involved. From question three to seven, the student was asked to select an answer from four possible options, in question eight the student was asked to make a detailed description of an infrared spectrum to identify the use of academic-scientific vocabulary. In question nine, two columns were requested to be related to information regarding the spectroscopic techniques studied. It is important to mention that the same type of questionnaire was used for both the Pretest and Posttest evaluation.

3. Results and Discussion

The results obtained from the evaluation of each of the pretest exams applied to the 45 students are presented, which were graded as follows: for question one the answers were Yes or No, for question two the answers Yes or No were considered. An example of the Pretest and Posttest exams carried out and required by the students are presented below in Figure 1 and 2, in both cases the total grade obtained for each test is included, in the case of questions 3, 4, 5 and 6 the question was considered answered if a circle was placed, an ✕ or a ✓ sign. In the case of question nine, it was considered as answered if the words were linked through a line or the letters that correlated them were placed.

The results were organized into two groups depending on the male and female gender in order to determine if there is a difference in terms of vocabulary management between genders, then the cumulative answers of each of the questions were grouped to determine between the data of the Pretest and the Posttest (Annex 1) if there is a significant difference per question and in a general way to determine both individually and as a group the gain of learning.Table 1 shows the cumulative results for each of the answers made in the Pretest and Posttest evaluation for each of the female participants.

Table 1.- Cumulative frequencies per question observed in the female gender.

Question	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Pre test	8	3	4	2	29	7	97
Post test	21	13	19	9	68	16	202
Difference	13	10	15	7	39	9	105
Pre test	38	14	19	10	34	33	46
Post test	100	62	90	43	81	76	96
Relativefrequency	62	48	71	33	38	43	50

In the same sense, Table 2 shows the cumulative results for each of the answers obtained in the Pretest and Posttest evaluation for the male gender.

Table 2.- Cumulative frequencies per question observed in the male group.

Question	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Pre test	11	3	4	4	30	8	122
Post test	22	21	22	14	68	14	204
Difference	11	18	18	10	38	6	82
Pre test	46	13	17	17	31	33	58
Post test	92	88	92	58	71	58	97
Relative frequency	46	75	75	42	40	25	39

To determine the learning gain by applying Hake's equation (*g*), the results obtained from each of the questions included in the Pretest and in the Posttest were organized, data that are shown in Table 3, in addition to indicating the gender of the participant, where the value of the individual learning gain could be determined. as well as group according to the learning gain scale using the equation shown below by [22]: [23]:

$$g = \frac{Post\ test\ -\ Pre\ test}{100\ -\ Pre\ test}$$

Scale range *Classification*
$0.70 \geq (g)$ High Gain
$0.30 \leq (g) \leq 0.70$ Medium Gain
$(g) < 0.30$ Low Gain

Table 3 shows the data obtained for the total number of participating students, where it is observed that in the case of male participants, the average value of the Pretest is 3.9 and the average value of the Posttest is 7.7. In the case of female participants, it was determined that the average value of the Pretest evaluation was 3.4 while for the Posttest it was 7.9.

It can be observed that the learning gain in both genders of participants was Medium, although there were participants who had a high gain according to Table 3, the average group value determined based on the evaluations of the Pretest and Posttest was also Medium.

We consider that, if the use of the terms where the difference with respect to the Pretest is reinforced and deepened, as shown in Tables 2 and 3, the value of the learning gain can be increased.To determine if the Pretest data for both genders conform to a normal distribution, the Shapiro-Wilk statistical test (Annex 2) was applied, determining that these data are distributed normally, which did not happen for the Posttest data.

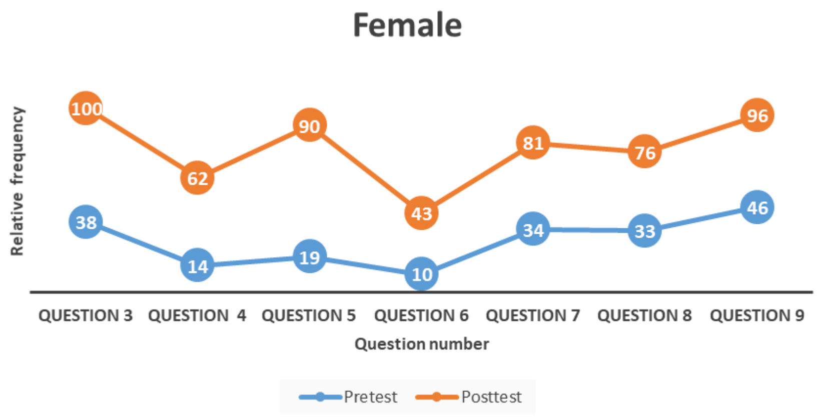
Table 3.- Data obtained from the Pretest and Posttest evaluation applied to the students of both genders who participated.

Gender	Pre test	Post test	*g*	Gain	Gender	Pre test	Post test	*g*	Gain
Female	1.0	7.0	0.67	Medium	Male	2.5	3.0	0.07	Low
Female	1.0	10.0	1.00	High	Male	4.0	9.0	0.83	High
Female	3.5	9.0	0.85	High	Male	1.5	9.7	0.96	High
Female	3.0	10.0	1.00	High	Male	3.5	8.1	0.71	High
Female	4.5	7.1	0.47	Medium	Male	3.5	5.7	0.34	Medium
Female	3.0	10.0	1.00	High	Male	3.0	10	1.00	High
Female	3.0	10.0	1.00	High	Male	3.5	8.6	0.78	High
Female	2.5	5.7	0.43	Medium	Male	2.5	4.0	0.20	Low
Female	2.5	8.6	0.81	High	Male	5.0	8.6	0.71	High
Female	5.0	7.2	0.43	Medium	Male	4.0	5.7	0.29	Low
Female	2.5	6.0	0.47	Medium	Male	4.5	8.0	0.64	Medium
Female	6.5	8.6	0.59	Medium	Male	3.0	8.6	0.80	High
Female	4.0	7.2	0.52	Medium	Male	3.0	7.2	0.60	Medium
Female	4.0	8.0	0.67	Medium	Male	4.5	9.4	0.89	High
Female	3.5	8.2	0.72	High	Male	5.0	6.8	0.36	Medium
Female	4.5	5.6	0.19	Low	Male	5.0	8.6	0.71	High
Female	4.0	10.0	1.00	High	Male	6.5	10.0	1.00	High
Female	3.0	6.0	0.43	Medium	Male	3.5	8.6	0.78	High
Female	4.5	6.8	0.42	Medium	Male	4.5	8.2	0.67	Medium
Female	4.0	10.0	1.00	High	Male	5.0	8.5	0.70	Medium
Female	3.0	5.7	0.39	Medium	Male	4.0	5.0	0.17	Low
					Male	6.0	8.5	0.63	Medium
X	**3.5**	**7.9**	**0.68**	**Medium**	Male	2.0	10.0	1.00	High
					Male	4.5	6.2	0.31	Medium
					X	**3.9**	**7.7**	**0.63**	**Medium**

In this same sense, the Maan-Whitney test (Annex 3) was applied to determine if there is a significant difference between the results of men and women for both the Pretest and the Posttest, the data shown in Table 3 were taken. It was determined that there is no statistically significant difference between the results obtained from the Pretest and the Posttest by the male and female genders.

In this sense, as mentioned with the results obtained, no significant statistical difference was observed between genders with respect to the overall learning gain by gender, although it is observed that in the case of the female gender, there was a greater tendency to obtain better results than men. Some authors mention that intelligence tests carried out on men and women suggest that, on average, neither gender male and female has more general intelligence than the other[20]; [21].Though people are equals in general intelligence, they are different in special forms of intelligence such as social intelligence and creative intelligence, the former being more commonly observed in women and the latter in men.

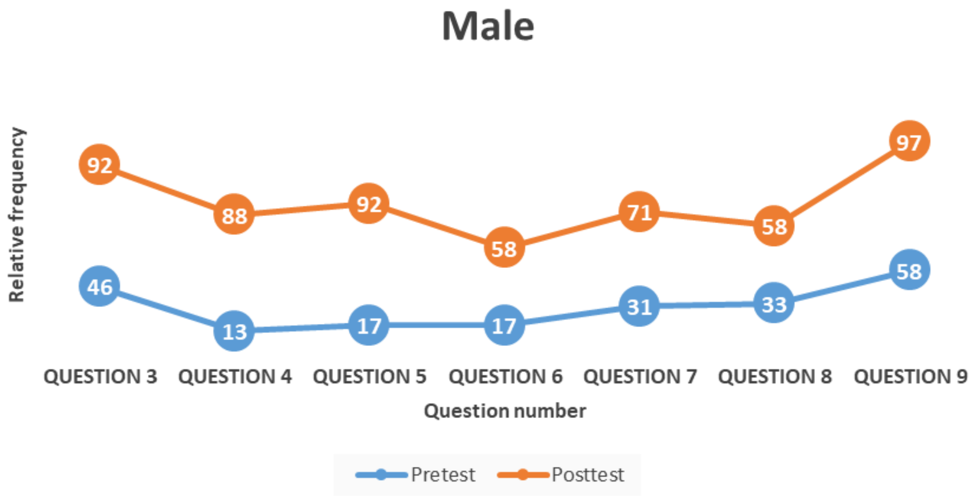
Additionally, and in order to determine if there is a significant difference between the results of the Pretest and the Posttest globally, the Wilconxon Sign Range test (Annex 3) was applied, where it was possible to determine that there is a statistical difference between the Pretest and the Posttest globally, since this same test confirmed that there is a significant difference between the Pretest and the Posttest in both genders.The data shown in Graph 1 allowed us to identify which of the questions presented a greater command of the academic-scientific vocabulary. In this sense, in the case of the female gender, the general answer to question four shows us that it is necessary to reinforce the issue of mass spectrometry and emphasize that the correct word to refer to the results in a spectrum of this technique is that of "FRAGMENT".



Graph 1.- Relative frequency *vs* question number observed in females

Question six, which corresponded to the selection of answer c) as the correct "BAND", was the one that showed the least general difference with respect to the question in the Pretest, which indicates to the teacher that more emphasis should be placed in the classroom so that the student recognizes the word "BAND" as the appropriate one to refer to a UV-Vis spectrum.In question eight, the smallest difference was observed, which is associated with the prose description of an absorption spectrophotometry spectrum in the infrared region, since the participating students made a very brief description of the spectrum and therefore very little use of the academic-scientific vocabulary they used.

A similar analysis was carried out with the data shown in Graph 2 that correspond to the frequencies of the answers of the male gender, which allowed the identification of those questions that presented a greater appropriation of the scientific vocabulary. In this sense, in the case of the male gender, questions six and seven were the ones that presented the least significant difference, information that allows the teacher to focus or delve deeper into the concepts that are related to this question. For question eight, it is proposed to deepen and propose prose description exercises of spectra acquired by absorption spectrophotometry in the infrared region, since the participating students made a very simple description of the spectrum and used a minimum of academic-scientific vocabulary.



Graph 2.- Relative frequency *vs* question number observed in males.

In this same sense and correlating questions three to eight, question nine encompasses a set of vocabulary that is used in the four spectroscopic techniques studied, in the case of women a significant difference is observed in terms of the increase in knowledge of scientific vocabulary, this difference was not observed in the case of the male gender.

The results were organized into two groups depending on the male and female gender in order to determine if there is a difference in terms of vocabulary management between genders, then the accumulated answers of each of the questions were grouped to determine between the data of the Pretest and the Posttest if there is a significant difference per question and in a general way to be able to determine both individually and as a group the learning gain. Although question eigth asked the student to write in prose the interpretation of a spectrum of the UV-Vis spectroscopy technique with the aim of making use of the scientific vocabulary they had learned in their face-to-face class, this was not sufficient to evaluate in greater depth the handling of the scientific terms of the technique. Therefore, we consider that the number of exercises of this type in the classroom can be increased to reinforce the vocabulary for each spectroscopic technique. Along these same way and as previously mentioned, the in-person classes used by participating students to study the different spectroscopic techniques included presentations of the fundamentals of the techniques using PowerPoint presentations, complemented by analysis of IR, UV-Vis, MS, and NMR spectra.

After the posttest application the participating students, it was found that the responses that yielded the greatest learning gains (Questions 3, 5, and 7) were those in which the question involved a graphic image of a spectrum. This leads us to believe that it could be beneficial for students studying these types of subjects to increase their spectral analysis of these techniques, since, according to our results, it allows them to better identify and correlate the scientific vocabulary of each of these techniques.

4. Conclusions

The results of the evaluation of the use of scientific vocabulary as a measure of knowledge of spectroscopic techniques showed that students generally had an average learning gain according to Hake's Equation, reflected in the knowledge, use and identification of spectra and specialized scientific vocabulary used in each of the different spectroscopic techniques studied. The results obtained from the Pretest and Posttest evaluation allowed us to visualize the concepts on which the teacher should focus in a more forceful way in the classroom, so that the student internalizes and manages more efficiently the academic-scientific vocabulary specialized for each spectroscopic technique. The statistical analysis showed that there is no significant difference in learning gain between men and women, but it was possible to demonstrate that there is a significant difference between the result of the Pretest and the Posttest within each gender. According to the statistical analysis, there was also no significant difference between the results of the students who reported having taken the subject and those who were taking it for the first time, which indicates that the previous knowledge they may have had was not significant.

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Declaration of interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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ANNEX 1

UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO
FACULTAD DE ESTUDIOS SUPERIORES CUAUTITLÁN
SPECTROSCOPY

Name:____

Gender:____

Semester:____

1.- Is this your first time taking the subject of Spectroscopy?

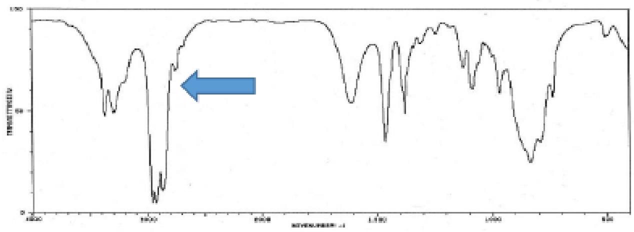
YES NOT

2.- Have you had training, courses, conferences, congresses where the topic of Spectroscopy is reviewed?

YES NOT

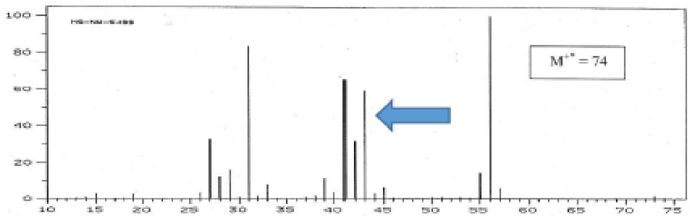
Below are a series of questions intended to assess your level of knowledge regarding scientific vocabulary in the field of spectroscopy.

3.- Based on the information previously acquired during your academic training, indicate which of the options should be used to refer to the response observed in the following spectrum:



a) signal b) band c) peak d) fragment e) response

4.- Based on the information previously acquired during your academic training, indicate which of the options should be used to refer to the response observed in the following spectrum:



a) fragment b) band c) response d) signal e) peak

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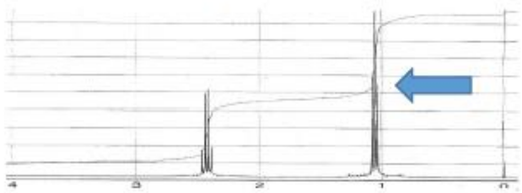
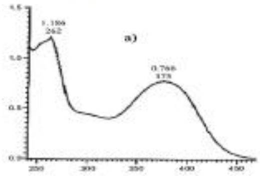
Pretest format 1/3

5.- Based on the information previously acquired during your academic training, indicate which of the options should be used to refer to the response observed in the following spectrum:



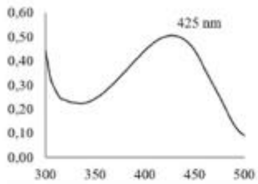
a) signal   b) peak   c) band   d) response   e) date

6.- Based on the information previously acquired during your academic training, indicate which of the options should be used to refer to the response observed in the following spectrum:



a) signal   b) peak   c) band   d) fragment   e) date

7.- Identify each of the spectra shown below, using the options listed.



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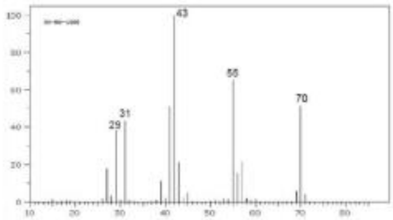

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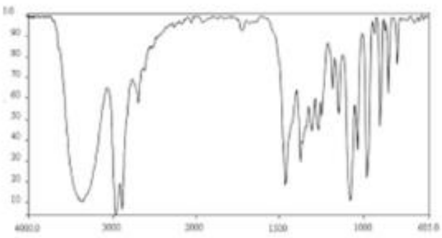

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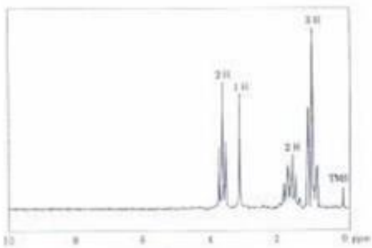


( )

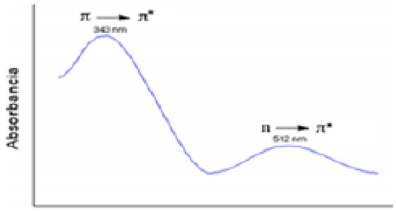
a) Mass spectra   b) UV-Vis spectra   c) Carbon nuclear magnetic resonance spectra

d) Infrared spectra   e) Proton nuclear magnetic resonance spectra

2

Pretest format 2/3

8.- Using the spectrum shown below, describe and interpret it, using the scientific vocabulary you have at this point.



9.- Match the following columns, which show information regarding spectroscopic techniques that will be studied in class.

a)	*m/z*	Molecular ion
b)	nm	Mass spectra units
c)	ppm	Wavenumber
d)	cm^{-1}	Nuclear Magnetic Resonance units
e)	Hz	Wavelength
f)	eV	J-coupling
g)	% ar	Mass spectrometric voltaje units
h)	*J*	Frecuency
i)	$M^{+\cdot}$	Abundance ion units
j)	λ	UV-Vis units

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Student's signature

3

Pretest format 3/3

ANNEX 2

Normality Test

	Gender	Shapiro-Wilk		
		Estadístico	**gl**	**Sig.**
Pre test (Y)	**Female**	**.951**	**21**	**0.363**
	Male	**.980**	**24**	**0.902**
Post test (X)	**Female**	**.882**	**21**	**0.016**
	Male	**.892**	**24**	**0.015**

It is observed that, for Pretest, both genders fit a normal distribution. However, for Protest they do not fit the normal distribution. It was decided to perform analysis with non-parametric statistical techniques.

ANNEX 3

Mann-Whitney Test

The test is used to indicate if there is a significant statistical difference between the results of men and women for both Posttest and Pretest.

Ranks				
	Gender	**N**	**Mean Rank**	**Sum of Ranks**
Pre test	Female	21	20.33	427.00
	Male	24	25.33	608.00
	Total	45		
Post test	Female	21	23.33	490.00
	Male	24	22.71	545.00
	Total	45		

Test Statistics[a]		
	Pre test	**Post test**
U de Mann-Whitney	196.000	245.000
W de Wilcoxon	427.000	545.000
Z	-1.286	-.160
Asymp. Sig. (2-tailed)	.199	.873
a. Grouping Variable: Gender		

What it indicates is that there is NO significant statistical difference between men and women in both the Posttest and the Pretest.

Wilconxon Test Rank.

It serves to indicate if there is a significant statistical difference between the results of Posttest and Pretest as a whole.

Ranks				
		N	Mean Rank	Sum of Ranks
Post test (X) – Pre test (Y)	Negative Ranks	0[a]	.00	.00
	Positive Ranks	45[b]	23.00	1035.00
	Zero	0[c]		
	Total	45		
a. Post test (X) <Pre test (Y)				
b. Post test (X) >Pre test (Y)				
c. Post test (X) = Pre test (Y)				

Test Statistics[a]	
	Postet (X) - Pretest (Y)
Z	-5.843[b]
Asymp. Sig. (2-tailed)	.000
a. Wilcoxon Test Ranks	
b. Negative Ranks.	

What it indicates is that there is a significant statistical difference between the Posttest and the Pretest overall.

Wilconxon Rank test by gender.

Ranks					
Gender			**N**	**Mean Rank**	**Sum of Ranks**
Female	Post test (X) – Pre test (Y)	Negative Ranks	0[a]	.00	.00
		Positive Ranks	21[b]	11.00	231.00
		Zero	0[c]		
		Total	21		
Male	Post test (X) – Pre test (Y)	Negative Ranks	0[a]	.00	.00
		Positive Ranks	24[b]	12.50	300.00
		Zero	0[c]		
		Total	24		
a. Post test (X) <Pre test (Y)					
b. Post test (X) >Pre test (Y)					
c. Post test (X) = Pre test (Y)					

Test Statistics[a]		
Gender		Post test (X) – Pre test (Y)
Female	Z	-4.017[b]
	Asymp. Sig. (2-tailed)	.000
Male	Z	-4.287[b]
	Asymp. Sig. (2-tailed)	.000
a. Wilcoxon Rank Test		
b. Negative Ranks		

What it indicates is that there is a significant statistical difference between the Posttest and the Pretest in both genders.