EXPERIMENTAL ACTIVITIES IN THE LABORATORY OF ANALYTICAL CHEMISTRY UNDER AN INQUIRY APPROACH

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ABSTRACT

This study analyzes the perception, development and improvement of the cognitive abilities of undergraduate students (of biochemistry and industrial chemistry) through the application of an inquiry methodology in the laboratory of analytical chemistry. The study was conducted during one semester. The instruments for data collection were a Test of Critical Thinking and a Questionnaire to determine the perception of the inquiry methodology and the traditional methodology, applied at the beginning and at the end of the semester. The results show an improvement in cognitive strategies and in the students' perception of the inquiry methodology. This is consistent with future job performance.

Keywords: Inquiry, laboratory activities, cognitive strategies.

1. INTRODUCTION

Problem solving and laboratory activities are fundamental tasks in the teaching and learning of science. Most teachers constantly use these as basic tools for learning, infrequently calling into question their validity or effectiveness or considering the critical nature of their formulation. The objectives of these activities are primarily focused on applying thinking skills: working techniques, data management, formulae and calculations, handling of instruments and equipment, cleanliness and tidiness, plus the strengthening concepts through observation of phenomena. In addition there is the acquisition of cognitive tools such as inference, generalization, abstraction, assumption and research planning[1]

The predominant instruction methods in university experimental activities conforms to the traditional style (also called expository, deductive or "recipe type"). This style relies exclusively on laboratory manuals to create a situation where the student performs the activity following a procedure established by the teacher so as to achieve the objective in question. There is another non-traditional style (also called student-centered, inductive or investigative) in which the particular student plans and carries out the research needed to answer a particular problem, enhancing the respective cognitive tools in a way the traditional style does not[1].

The cognitive strategies of interest in this study are Critical Thinking and Problem Solving through the application of an Inquiry Methodology.

Critical thinking is defined as reflective thinking that is focused on deciding what to believe or what to do [2-3].

Firstly, critical thinking is a reflective activity. Its goal is often not to solve a problem, but to better understand its nature. It is focused, since it involves thinking about something you want to understand better. The purpose of thinking critically is to evaluate information in a way that allows us to make well-defined decisions[4]. Moreover, problem solving is defined as a cognitive process involving four steps[5]. The first is to locate the problem, then to clearly define it, and develop good solution strategies, it should then be evaluated based on the primary objective, and finally, the problem must be rethought and redefined over time. Under this view, inquiry -based learning places emphasis on the resolution of authentic problems, i.e. those that occur in everyday life, in addition to allowing students to approach scientific inquiry. Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on evidence derived from their work. It also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, and of how scientists study the natural world.

Some authors claim that the following skills are necessary to develop scientific inquiry:

a) Identify questions that can be answered through scientific investigation.

b) Design and conduct a scientific investigation.

c) Use appropriate tools and techniques for collecting, analyzing and interpreting data.

d) Develop descriptions, explanations, predictions and models based on evidence.

e) Think critically and logically in order to relate the evidence and the explanation.

f) Recognize and analyze alternative explanations and predictions.

g) Communicate scientific procedures and explanations.

h) Use mathematics in all aspects of scientific inquiry [6-7].

These skills can be promoted and developed in students in their learning spaces, such as experimental investigation-based activities, the most prominent levels of which are the following: 1) confirmation experiments related to cognitive activities involving low-level tools, e.g. data collection guided by a procedure; 2) structured inquiry in which the teacher asks a question based on a problem and students seek answers through the implementation of a procedure; 3) semi-structured or guided inquiry, where a problem is posed to students but they must design the research in terms of a research question derived from the initial problem; 4) finally, at the highest cognitive level we find open inquiry, in which students are allowed to raise their own issues and plan an investigation to obtain well-reasoned answers[8-9].

There are also significant issues concerning the capabilities of experimental activities within science learning. Some research shows that there is little consensus regarding the utility of experimentation in the learning and/or reinforcement of concepts, the acquisition of skills, meaningful learning, extrapolation to daily life, etc. There are two main reasons for this: the structuring of practical work (and reduced procedures due to time constraints), and a mismatch of the purposes of the teaching and the aims of the students. For example, one study compared the processes of thinking exhibited by students in a traditional setting with those exposed in investigatory environments. As the first is based on encouraging students to deduce, while the second encourages them to induce, differences are to be expected. Shepardson found that the thinking processes of laboratory students were focused on procedural tasks, while the thoughts of other students in the investigative environment focused on data analysis and the search for the meaning of these results [10-15].

The need for research arises from the finding that university students studying subjects in the area of analytical chemistry in their professional training generally show theoretical and practical deficiencies in relation to these. This is also often reflected in their qualifications, and arrangement to confront the laboratory work. It would appear that the students simply want to finish the activity quickly, without making the most of the opportunity to deepen their reflection and questioning of their own learning. In this context we find the following research question: How can we improve and enhance the cognitive strategies of students studying Analytical Chemistry in scientific degree programs?

The main objectives of this study is: *to improve the skills in the development of scientific inquiry through semi-structured research methodology in the laboratory of Analytical Chemistry; and to evaluate the impact on university students in the application of a research methodology versus a traditional methodology in analytical chemistry laboratories.*

2. METHODOLOGY

The experimental design took the form of a field experiment, having the advantage of greater generalization or transferability to educational situations

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as it is conducted in contexts that are real or very similar to these[16]. For this research, we propose the following hypotheses: 1) *The application of an Inquiry Methodology in the Analytical Chemistry Laboratory enhances critical and argumentative thinking in university students as well as the skills and abilities they need to tackle the problems associated with experimentation, thus bringing them closer to scientific inquiry*, and 2) *The investigative methodology encourages students in the assessment of cognitive strategies developed during problem solving and through further experimentation, as opposed to their perception of the classic laboratory activities*. As the dependent variables are the cognitive skills (inquiry and analysis) of the university students, while the independent variable was the experimental work in the laboratory on the subject of Analytical Chemistry. The variable is modified through the application of a research methodology using structured and semi-structured or guided inquiry.

The structured inquiry approach was based on a research question (derived from a problem), to which the students gave answers by following a set procedure. Semi-structured inquiry was then employed, during which any issues of interest to the students were raised, thus generating questions and then addressing one of them to seek answers through experimentation.

The sample consisted of 64 students majoring in Biochemistry and Industrial Chemistry who attended the course of Instrumental Analysis in the sixth semester in both curricula, which is part of an axis of 3 analytical chemistry courses all involving weekly laboratory sessions. This course is the second course of Analytical Chemistry for both degree programs, with the prerequisite of two prior General Chemistry courses, a course on thermodynamics for Biochemistry, 2 Physical Chemistry courses for Industrial Chemistry and one on General Analytical Chemistry, which covers the thermodynamic principles of competitive steady-states in aqueous solution and its application for the development and control of volumetric and gravimetric methods.

The practical activity is related to the content of the units on Molecular Absorption Spectroscopy and Atomic Absorption Spectroscopy and is the culmination of a previous experimental learning axis, consisting partly of traditional guided practices and semi-structured practices where the students develop technical skills for managing molecular and atomic absorption spectrophotometers, the preparation of standards and calibration curves, quantifications in synthetic solutions, mixtures of analytes and error determination. All these sessions were distributed over 11 laboratory sessions in 11 weeks:

1. Molecular Absorption: Correct use of instrument, familiarization with pieces and parts. Drawing of external calibration curves and standard addition.
2. Molecular absorption (mixture analysis).
3. Analysis of a sample (1): figures of merit, quantification limit, linear range, precision, accuracy.
4. Analysis of a sample (1). quantification
5. Flame atomic absorption. Correct use instrument familiarization pieces and parts. Plotting a calibration curve.

The students are given Sample Problem 2 which thy must analyze and understand from session 6 to session 11.Sessions 1 to 4 deal with molecular absorption spectroscopy. The first 3 sessions will use structured practices to develop technical skills in handling a molecular absorption spectrophotometer, its calibration, and the evaluation of analytical figures of merit. The third session is the analysis of a sample synthetic problem, which is an iron solution wherein the concentration of the analyte in solution is based on a structured molecular absorption method to determine the phenanthroline ligand.

The fourth session is a semi-structured session where students must determine Fe in a semi-synthetic test sample (e.g. a drug) using on the methodology developed in Session 3. The idea is for students to propose a solution treatment analyte and the dilution factors deemed most appropriate for quantification, keeping the instrumental conditions of Session 3.

The fifth session is a structured session on the management photometer and atomic absorption spectrophotometers worked in both absorption and atomic emission modes. This session is focused primarily on familiarizing the students with the parts and components, the sensitive controls, optical alignment, preparation of basic standards and finally plotting calibration curves.

After this the traditional axis begins, with open practice from session 6 to session 11. To develop this axis, the students are given one of several analytical problems consisting of the determination of an analyte in a sample real problem for which there is no validated methodology. Examples of these are:

- Determination of Cu in agricultural soils.
- Determination of Na in foods.
- Determination of Pb in contaminated water.
- Determination of K in human urine.

For these analytical problems students must propose an entire analytical sequence corresponding to the collection and processing of the sample, instrument conditions such as analytical wavelength, concentration range for calibration of the mixture for the flame atomizer, system quantification, evaluation of analytical figures of merit (precision, accuracy, limit of detection and quantification, linear range) and finally expression of the final result in a written report. From proposal for the development of the analytical method to its implementation and validation, students have 6 experimental sessions in 6 weeks. Each week students should also request a list of materials and reagents a week in advance. During these sessions, in addition to assessing the final report and the quality of the experimental procedure was also assessed in terms of the proper use of instruments, safety standards, washing equipment punctually, etc.

The statistical basis for the development of these practices is based on IUPAC standards for the validation of analytical methods[17]. The physical basis of the techniques involved includes Beer's law, the Boltzmann distribution and the laws of optics and electromagnetic radiation (absorption, emission, diffraction, dispersion), all known and reported in Instrumental Analytical Chemistry texts[18]. Both the statistical basis and the physical principles of the spectroscopic techniques are reviewed in the respective lecture course which was developed in parallel to the experimental sessions. The experimental activities use guides designed from the investigation perspective, where initially a structured guide was used, in which students worked from a problem given that required empirical testing in order to be resolved. Subsequently, the students raised an issue of interest which could be addressed from the investigation perspective, posing questions, proposing hypotheses, designing procedures, analyzing results and drawing conclusions.

Data collection was conducted using the Critical Thinking Test to assess cognitive skills before and after the experimental investigation activities, and a Questionnaire was also used to obtain the students' opinion regarding this methodology and the traditional methods used in laboratories for Analytical Chemistry.

2.1. Critical Thinking Test

The version of the test used in this study was translated, adapted and validated in a thesis of education at the Southern University of Chile [19]. This instrument was originally created by a committee of experts from the Educational Testing Service and the College Board in 1986 for the New Jersey Department of Higher Education's College Outcome Evaluation Project (COEP). In this test the subject evaluates the information in two cognitive dimensions, Inquiry and Analysis.

The inquiry dimension refers to the possibility of working or not working to plan an information search (systematic procedures to construct, understand and extract ideas, classify and evaluate relevant material). The dimension analysis refers to the possibility that the person has to work or not work to formulate hypotheses, design strategies to break the information. This includes the application of techniques, rules and models to solve problems, show space, flexibility and creativity; assess conjectures, evidence reasoning, find relationships and make conclusions[19]. These two dimensions were evaluated as follows: 5 parts for inquiry (27 total points) and 2 parts for analysis (10 total points), questions were associated with "climate El Niño", with support from pictures and documents.

2.2. Student Opinion Questionnaire

The questionnaire used in this study aimed to gather the opinions of students regarding the practical work with the research methodology and the traditional methodology. The topics evaluated were: learning, problem solving skills, group work and scientific research. In addition, two open questions were added in order that the students could express their pleasure or displeasure regarding the two respective modes.

3. RESULTS AND ANALYSIS

3.1 Critical Thinking

In the Critical Thinking Test the average values of the scores associated with each dimension (Inquiry and Analysis), both pre and post-test were calculated and the standard deviation and coefficient of variation were also determined. The Dixon test or Q Test was applied[20]. This test was applied to the initially dubious data, which were statistically accepted and considered in subsequent statistical calculations.

With regard to the student opinion questionnaire for the quantitative and comparative analysis, obtaining percentages for each topic evaluated, the most representative responses were chosen for transcription and qualitative analysis of the open questions.

The results are presented along with the discussion of the assessment of the critical thinking of the students participating in the course, which is defined as the reflective thinking that is focused on deciding what to believe or what to do[9].

3.1.1. Analysis of the results of the pre and post-test.

Table 1 presents the average score obtained by the students in the two dimensions assessed in the Critical Thinking Test both the pre-test and posttest.

Table 1 Average Score, percentage, standard deviation and percentage coefficient of variation for the pre & post-test.

Dimension	Average score Percentage				Standard Deviation		% Coefficient of variation	
	Pre-test 7	%	Post-test 8	%	Pre-test	Post-test	Pre-test	Post-test
Analysis	7	70	8	80	1	1	15	11
Inquiry	16	59	19	70	2	2	14	12

The initial profile of the students prior to the lab work can be defined as normal in the scale of analysis, this includes the student's ability to formulate hypotheses, design strategies to break down the information, as well as the application of techniques, rules and models to solve problems, show flexibility and creativity, assess conjectures, evidence reasoning, draw conclusions and find relationships [17]. This profile is partly due to interventions by teachers, as students usually read and analyze scientific papers, bringing them closer to the hypotheses and research designs. All these cognitive skills must be developed in science degree programs, which are aimed at research and development areas which primarily can be achieved with the implementation of pilot activities at different levels of depth.

For the inquiry dimension, the results obtained by the students show a low average level. This dimension refers to the ability to be skillful or not to plan a search for information, including: building systematic procedures, understanding and extracting ideas, and classifying and evaluating relevant material. This result is due to the use of traditional laboratory practices reflected in the design of protocols for solving problems, failing to give students the opportunity to make changes and to achieve the expected and successful results.

After completing the course, the Critical Thinking Test was applied, aiming to evaluate any improvement in cognitive skills; these results are shown in Table 1 as well as the parameters associated with the distribution of the results. After performing the investigative and laboratory experiments, the scores obtained can be used to qualitatively describe the student profiles, obtaining a standard classification in both dimensions, Analysis and Inquiry.

From a qualitative point of view, these results do not demonstrate substantial changes in the Analysis dimension, since in terms of scores on both tests, it is possible to further describe this dimension as normal. However, this does not imply that there were no changes in the cognitive profile of the students of experimental activities. Moreover, the increase in the average score on the Inquiry dimension is sufficient for the cognitive profiles to be classified as normal in this dimension, which was initially in the medium low. This new description suggests that in the experimental work the students have developed in their ability to extract information, and to classify and evaluate it, etc. Essentially, they have improved their competence for investigating the cause and effect of an event, a skill that will no doubt be developed in the area of science and research, and which is also fundamental in study programs to which these university students belong. These results demonstrate that the students are able to solve problems through personal information processing, an ability that is advantageous from the point of view of their professional and personal formation.

Regarding the homogeneity of the student responses on the post-test, an improvement can be seen in this area (relative to pre-test), shown by the fact that the percentage coefficient of variation in both dimensions are virtually identical. This means that the experimental activities carried out under the investigative approach itself influenced the majority of students, and because of this, they obtained similar scores on the different dimensions.

3.1.2. Results and Analysis of Critical Thinking and the Inquiry Methodology

For the results obtained from the pre and post-Test of Critical Thinking from a statistical point of view and its relation to the Inquiry Methodology and experimentation, a test of statistical significance (t-test) was performed to determine if the difference between the average scores for each dimension were significant. To this end, the null hypothesis and the alternative hypothesis were proposed, considering the same assumptions for both the Analysis dimension and the Inquiry dimension.

Null Hypothesis: There is no significant difference between mean scores on the scale before and after the experimental work in the laboratory of Analytic Chemistry.

Alternative Hypothesis: There is significant difference between mean scores on the scale before and after the experimental work in the laboratory of Analytic Chemistry.

Figure 1 presents the values of the average scores obtained for the Critical Thinking Test evaluated at the beginning and at the end of the experimental activities; the results of the significance test are also shown.

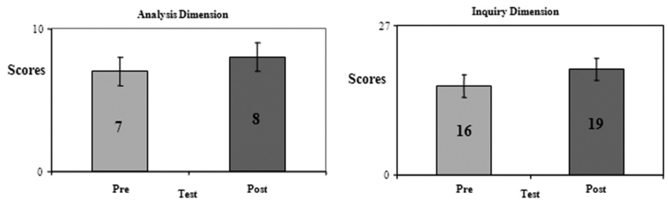

Figure 1 Scores obtained for dimensions Analysis and Inquiry

The significance test was applied using the scores for all students participating in the test, prior to the data review via the Dixon test. This was done using the t-test to compare means between two samples, in this case in the pre and post-test data sets. For both dimensions, Analysis and Inquiry, the same statistic was calculated. The theoretical value of T at 95% confidence and for a tail was used as it was expected that the values obtained for the Post-Test would be higher in both dimensions.

The results of the test of significance, for both dimensions, were the rejection of the null hypothesis and acceptance of the alternative hypothesis. Therefore, in both dimensions (Inquiry and Analysis) it can be considered that the mean scores obtained were statistically different to a confidence level of 95%. This significance test allowed us to give reliability to the results, identifying an improvement in cognitive abilities in the university students after six months of work in experimental activities under the inquiry style.

Finally, the results of the Critical Thinking Test show that the application of the Inquiry Methodology in experimental activities for Analytical Chemistry improve initial cognitive skills in university students by about 10% in the cognitive domains assessed by the instrument in question.

Considering the probability that this instance was the first time the students were presented with this new form of experimental activity, and it included the first subject area to be structured in this way, we can propose the following question: will incorporating the practical application of this methodology into more courses achieve more significant improvements in the development of cognitive skills of university students? Undoubtedly, this is a challenge in courses with experimental support in science degree programs.

3.2. Student Opinion Questionnaire

The questionnaire was administered at the end of the semester and consisted of two parts; the first is a series of statements in which students indicated preference for the investigative or the traditional style, while the second part included two open questions. The main results (percentage parameter) for assertions presented in the research methodology and in the traditional methodology are analyzed below. This is followed by a descriptive analysis of the answers given to the open questions.

3.2.1. Quantitative analysis

Questions were asked on 5 topics related to the experimental activities: learning, problem solving, skills, group work and scientific research. The student marked T (Traditional) or I (Inquiry) when considering that the statement presented is best suited to one or another style, see Table 2.

Table 2 Responses for the student opinion questionnaire

Topics	Percentage	
1) With regard to learning activities associated with the practice	Traditional	Inquiry
a. I learned a lot of chemical principles in the laboratory.	55	58
b. I did not learn anything new in this laboratory.	6	5
c. I did not learn anything new in this laboratory, but it helped me develop a better understanding of theoretical concepts.	34	39
2) With respect to problem solving		
a. The style of the laboratory did not influence my way of solving research problems.	50	9
b. The laboratory style helped me to solve research problems.	13	80
c. I do not know if this style helped me or not.	34	11
3) With respect to the skills acquired		
a. This type of lab allowed me to improve my ability to design procedures; and to collect, analyze and interpret data.	19	52
b. This type of lab would not allow me to improve my ability to design procedures; and to collect, analyze and interpret data.	44	3
c. This type of laboratory did nothing to improve the skills I had already acquired.	34	5
4) With respect to group work		
a. This style promotes collaborative laboratory work, improving my relationships.	28	75
b. This style does not promote laboratory collaborative work, improving my relationships.	16	8
c. This laboratory style does not greatly affect my relationships.	53	17
5) The format of the lab helped me better understand how scientific research is performed		
a. Yes	13	80
b. No	33	11
c. I don't know	52	9

Figure 2 shows the results in bar graphs displayed by topic, allowing better visualization of the differences in the percentages for the two styles of laboratories and providing descriptive analysis and discussion of each.

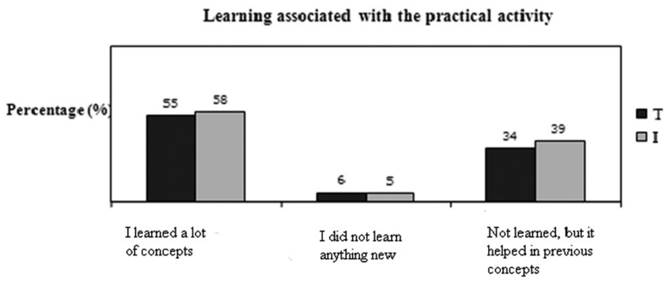

Figure 2 Percentages obtained for Traditional and Inquiry style

With respect to the learning associated with the practical activity, in general terms it can be seen that there are no appreciable differences between the percentages obtained for traditional laboratory activities and the investigative option. However, there are differences among some answer choices, yielding the highest percentages for the "I learned a lot of chemical principles in the laboratory", which exceeded 50% for both styles of work in the laboratory. Less than 10% of the students believe the laboratory styles did not benefit them. Thus, it is explained that a high percentage, about 40% of students believe that laboratories facilitate the understanding of previously-learned theoretical concepts. Pilot activities, whether associated with traditional or investigative methods, aim to give students a different view of the content learned in lectures. The other half of the students surveyed were able to better perceive the target (in the statement "I did not learn anything new, but it helped me in understanding previous concepts"), although there are no significant differences between the percentages for the traditional style and the inquiry methodology. It is likely that students confuse "learning knowledge (principles)" with "acquire skills", which is what we have tried to work on with the research methodology, and is also perhaps the cause of the high percentages obtained in these two statements. Based on student responses, it is not possible to determine a clear trend for either style in the laboratory in terms of which style they believe is more favorable for learning or the reinforcement of prior knowledge.

As shown in Figure 3, on the topic "problem solving", there are differences in the percentages obtained for the two laboratory styles. Most of the responses indicate that traditional laboratory work does not influence the way the student solves problems of an experimental nature. While a high percentage of the students feel that the investigative laboratory style did help to improve the way problems were solved. Thus, it can be seen that the investigative laboratory style allows students to improve the way they address problems associated with experimentation.

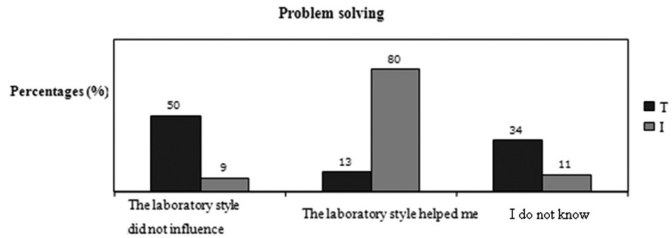

Figure 3 Percentages obtained for Traditional and inquiry styles.

One of the objectives of applying the research methodology was to improve and develop cognitive tools in the university students who participated in the course, identifying whether the students were able to assess the possibilities offered by implementing this methodology in their experimental activities, showing the high percentage for the assertion "Lab style helped me solve research problems" over the traditional style: "Lab style did not influence my way of solving research problems". These results demonstrate that the application of the research methodology improves and develops students' cognitive tools.

Given the question of whether the laboratories enabled the students to improve their skills such as procedure design or information gathering, data analysis and interpretation, Figure 4, the students showed marked differences in their answers, as reflected in the percentages obtained and differences between these.

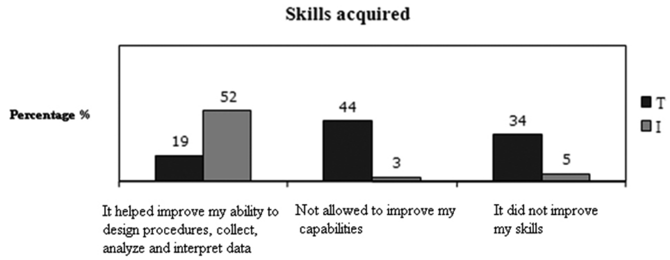

Figure 4 Percentages obtained for the skills acquired in the traditional style and in the inquiry

While the percentage obtained for the approval of the inquiry style was only 52%, the difference is significant when compared with the traditional style (19%). From another point of view, the negative statements regarding skills are low for the investigative style (3% and 5%) in contrast to the traditional style. Therefore, these results support one of the goals of this paper.

The fourth topic refers to group work which is classic element of experimental activities. The students were asked if any of the laboratory styles favored the development of interpersonal relations, or if it largely failed to influence their actions, Figure 5.

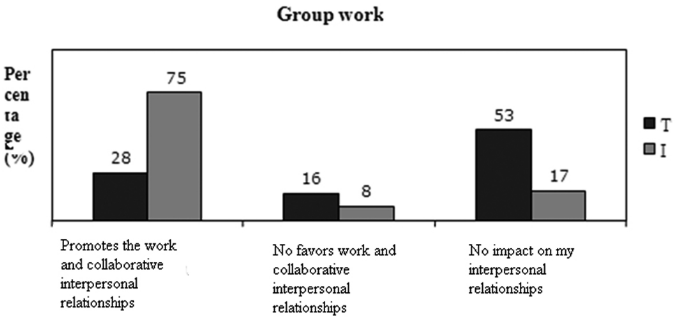

Figure 5 Percentages obtained for the group work in the traditional and the inquiry style.

The highest percentage obtained corresponds to the choice of investigative experimental activities that promote both collaborative work and interpersonal relationships. Moreover, a low percentage of students think that these styles of work in the laboratory do not favor social relations in experimental activities.

In two of the assertions presented to students, there are significant differences in the percentages obtained. The investigative laboratory promotes teamwork, whereas the traditional lab does not encourage collaborative work. These results are consistent with these styles of experimental work and in traditional practices students are governed by a process, leading to minimal planning and coordination in the laboratory, while investigative activities require students to plan and coordinate to achieve their experimental goals for the issues raised. This in turn enhances the ability of communication between peers and their teachers, as it is necessary to exchange information, which practically does not occur in traditional activities.

The last question was "laboratory format enabled me to understand how scientific research is conducted", Figure 6.

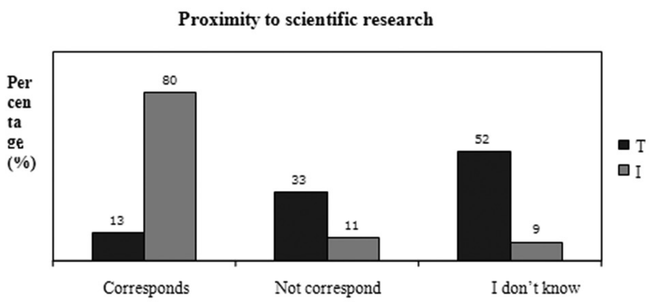

Figure 6 Percentages obtained for proximity to scientific research for traditional and inquiry style

This is an important topic, since it determines which model of scientific research the students possess and how concordant it is with this new style of experimental work that is presented to them, as they face more real problems and should use logical problem resolution to realize their goals. Thus, these results clearly show that this approach brings students closer to scientific inquiry, and a high percentage of the students believe that his is so. However, we should not dismiss the fact that there are students who believe that traditional research does reflect scientific inquiry, implying the belief that the research is based on the reproduction of procedures established many times and this is more important than the planning and analysis of experiments, which is still ingrained in many students under a strict model of doing science, a model that must be changed by implementing more open methodologies that require more intellectual development and creativity on the part of university students on degree programs that lean towards the area of research.

3.2.2. Descriptive analysis of the results

The questionnaire consisted of two open-ended questions aimed at obtaining the students' opinions regarding the laboratory styles:

1) "If in the future you could choose the laboratories for Analytical Chemistry, would you prefer the traditional style or the investigative style? Why? "

2) "Please comment on what you liked, what you did not like and what you would change in relation to both styles of laboratory activities seen in these subjects."

With regard to the first question, the majority of students preferred the investigative style. The basis for this choice was varied, but basically they liked to see in this approach a possible reflection of their future work, for example in the following response:

a) Investigative: it allows the student to have a more realistic approach to what will be their future work, which will be faced in the collection and analysis of data in projects that do not always require a simple approach. In contrast, the traditional format just follows procedures that were studied beforehand, that while contributing to the sense of acquiring skills, it is not as close to reality as the inquiry format.

This response is accurate in noting the main difference between the traditional and the investigative laboratory styles, i.e. the fact that the former follows established procedures. The following is another answer that refers to group work and its close relationship to the work environment: "I prefer the investigative style, because it helps personal research, promotes collaborative work and it also helped me to better relate to my peers as when we enter the workforce we will meet people with different points of view, and we must be able to accept criticism". This response also refers to an important point, tolerance toward others, listening and expressing opinions, skills that should also be developed in parallel to academic instruction while at university. In laboratory work under the research methodology, these instances can be created, as students should communicate, plan, review, etc. to make arrangements in accordance with a common goal. Another example of a response that reflects this is: "I would prefer the investigative style, because it shows us more about what real problems we would face in a professional future than the traditional style does. It also gives incentives towards scientific research rather than following an almost unchanging static recipe".

For this first question, there were also students who opted for the traditional laboratory, but not for reasons of learning and personal development with a view to their future, but for the practical ease of this type of laboratory, for example, "I would choose the traditional style because the group was composed of only 2 people while the investigative laboratory had many people forming each group (5 or 6 people), the only thing I learned was to use the absorption equipment". This is a clear example of students who consider the experimental activity as a necessary step to comply with the requirements of the course. It shows no insight into the activity, the benefits of group work, study and discussion of the progress of their investigation, it only considers possible advancement in the academic goals and technical management. The following response reflects little interest from the student to improve their experimental skills and a lack of appreciation of the experience acquired through inquiry.

Finally, a small group of students chose a mixture of both styles: "I believe that complemented both styles work correctly. It's good that information sessions are done first and then this can be applied independently".

Thus it has been said that most of the students who participated in the course have been left with a good perception of the inquiry methodology, recognizing the educational value of skills and experimental skills and development of potentiality that will help spur their future profession.

Regarding the second question: "Please comment what you liked, what you did not like and what you would change in relation to both styles of lab seen in these subjects", some answers are: "I liked this new style (inquiry) that we develop methodologies using skills learned beforehand, so we can better understand scientific endeavor. It is also a good way to motivate students as it is as if it was our own "research."

a) "While the traditional format does not come close to the reality of what our future work will be, as we are seeing this material in only the first year of analytic chemistry, it is not a bad format because it at least gives an indication of what we will face. The sample problem stands out, as it allows us to propose procedures and apply what we have learned. Regarding the inquiry format, I have no major criticism".

b) "Of the traditional style, I would change the fact that it is very structured, maybe a more personal research style would help. And with respect to the investigative method, I would make it more serious and as dedicated as the traditional style". These examples once again show the general preference of students for experimental activities that bring them closer to real scientific research and that emulate their possible future work. They value the fact that traditional activities are in the first subject in this area, as this allows them to acquire certain skills that favor their passage to investigation, all in a more organized and structured environment, which apparently gives students more confidence in their experimentation. In addition, they described the investigative work as more "free" and seemingly less "serious" than traditional activities, which can be explained by the limited access that university students have to this type of methodology. They are used to the rigid structure of traditional guided lessons and have little experimental freedom, which surely makes them confuse "serious" experimental laboratory work with "productive" work. Productive in the sense that experimentation is not only a process of reproducing and reaching the "expected and correct result" but experimentation develops and enhances the students' capacity for logical and scientific reasoning, which is what is ultimately sought through investigative work, not only to find the "right answer" (classic goal of traditional activities), but for students to be able to get their results logically and to be able to solve the problems generated in the same work, in both laboratory stage and it planning, while at the same time ensuring the personal and social development of students.

Finally, we must mention that now the literature shows that the inquiry methodology is being implemented mainly at primary and secondary education, and almost no information is available regarding their implementation at university level. However, these findings show their application in higher education improve the cognitive skills of analysis, critical thinking and problem solving, which are strengthened during the development of experimental activity and so will benefit their future job performance.

4. CONCLUSIONS

It was possible to improve the skills and abilities necessary to develop scientific inquiry in university students through the application of a semi-structured inquiry methodology in the laboratory of Analytical Chemistry. This was shown by an increase of about 10% in the evaluation of the dimensions of Inquiry and Analysis (through the questionnaire or the Critical Thinking Test), which can be considered successful as it involves only a single subject and students training area. The results allow us to argue and corroborate the first hypothesis of this study, in which it was suggested that the inquiry methodology improves students' cognitive skills and moves students closer to scientific inquiry.

The impact generated on university students by the application of this research methodology versus the traditional methodology in laboratories of Analytical Chemistry was assessed in part with the Critical Thinking Test, showing improvements in their intellectual abilities. The aim of this research was focused on the independent cognitive skills and academic performance of the participants. Regarding the objective of evaluating this impact, the questionnaire proved to be a useful tool, concluding that the students accepted the inquiry methodology as a working strategy in the laboratory, valuing these instances to improve and develop their relationships with their peers, their analysis capabilities, their abilities for design and reflection, and thus bringing them closer to scientific inquiry. These findings thus support the second hypothesis, which refers to students valuing the skills and abilities that can be developed through this methodology, unlike what happens with traditional laboratory activities. This is confirmed in the responses to the open questions. In the survey the students mention that the inquiry method allowed them to develop their skills and cognitive skills of scientific reasoning. With regard to the traditional laboratory, although not entirely rejected, it was suggested for initial training in this subject area, as it would allow the students to acquire some initial skills and guide them (in a more structured environment) through the basic concepts of Analytical Chemistry.

Part of the good results of this study are because in the subject in which the methodology was implemented it is possible to work in parallel on practical activities with instruments and on more sophisticated methodologies that are close to labor practices in analytical chemistry, which is undoubtedly motivating factor for the students, as they can see more benefits in terms of their training. For purposes of this study, it has been mixed with the investigative approach, creating a powerful methodology to improve and develop cognitive skills in university students.

Finally, recalling the research question that led to the hypotheses and initial goals, does the application of the Inquiry methodology in an Analytical Chemistry laboratory improve cognitive strategies in university students? The answer obtained in terms of the results is good and it can also be applied in other scientific subject areas such as Organic Chemistry, Biochemistry, Inorganic Chemistry and others, because these areas need to develop diverse experimental activities.

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