



REVISTA

CÁTEDRA

Open research in laboratory practice to learn Chemistry in high school students

*Investigación abierta en la práctica de laboratorio y el
aprendizaje de la Química en los estudiantes de
bachillerato*

Fernanda Faicán-Juca

Unidad Educativa Nuestra Familia, Cuenca, Ecuador

mffaicanj@nuestrafamilia.edu.ec

<https://orcid.org/0009-0003-9033-381X>

Renato Manzano-Vela

Escuela Superior Politécnica de Chimborazo, Riobamba, Ecuador

Escuela Politécnica Superior, Facultad de Recursos Naturales

dennis.manzano@esepoch.edu.ec

<https://orcid.org/0000-0002-7834-276X>

(Received on: 05/09/2023; Accepted on: 25/10/2023; Final version received on: 02/12/2023)

Suggested citation: Faicán-Juca, F. y Manzano-Vela, R. (2024). Open research in laboratory practice to learn Chemistry in high school students. *Revista Cátedra*, 7(1), 94-108.

Abstract

Experimentation as a methodological strategy used in the teaching-learning process in chemistry presents a stagnation in the acquisition of knowledge, skills, and indispensable abilities. Currently, practices are based on methodically following the procedure given in a laboratory guide, causing a passive learning, where the student is not directly involved in building their own knowledge. For this reason, the purpose of this study was to apply open research in laboratory practice, since it is a methodology based on constructivist learning. Its relationship with the learning of chemistry was investigated, in addition to determining its influence and identifying its contribution to it. This research was non-experimental and correlational in scope. On the other hand, a survey and an evaluation test were applied to 125 high school students of the Nuestra Familia Educational Unit. As main results, a positive, moderate, and significant correlation was obtained between the open investigation in the



[Licencia Creative Commons Atribución 4.0 Internacional \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/)

laboratory practice with the learning of Chemistry. In addition, the results of the evaluation test show a positive influence by obtaining 75% of students who reach and master the learning. While 73.60% of students consider that the open research contributes considerably in the acquisition of learning. As a consequence, the applied methodology presents a superior cognitive contribution by developing and strengthening the research process and executing it in the laboratory.

Keywords

Learning, experimentation, open inquiry, laboratory, Chemistry.

Resumen

La experimentación como estrategia metodológica empleada en el proceso de enseñanza-aprendizaje en la Química presenta un estancamiento en la adquisición de conocimientos, destrezas y habilidades indispensables. Actualmente, las prácticas se basan en seguir de manera metódica el procedimiento dado en una guía de laboratorio, provocando un aprendizaje pasivo, donde el estudiante no se involucra directamente en construir su propio conocimiento. Por esta razón, el presente trabajo de estudio tuvo como finalidad aplicar la investigación abierta en la práctica de laboratorio, al ser una metodología basada en el aprendizaje constructivista. Se investigó su relación con el aprendizaje de la Química, además de determinar su influencia e identificar su contribución en la misma. Esta investigación fue de tipo no experimental y de alcance correlacional. Por otra parte, se aplicó una encuesta y un test de evaluación a 125 estudiantes de bachillerato de la Unidad Educativa Nuestra Familia. Como principales resultados se obtuvo una correlación positiva, moderada y significativa entre la investigación abierta en la práctica de laboratorio con el aprendizaje de la Química. Además, los resultados del test de evaluación demuestran una influencia positiva al obtener un 75% de estudiantes que alcanzan y dominan los aprendizajes. Mientras que el 73.60% de estudiantes consideran que la investigación abierta contribuye considerablemente en la adquisición de aprendizajes. Como consecuencia la metodología aplicada presenta un aporte cognitivo superior al desarrollar y fortalecer el proceso investigativo y ejecutarlo en el laboratorio.

Palabras clave

Aprendizaje, experimentación, investigación abierta, laboratorio, Química.

Introduction

The Ministry of Education of Ecuador promotes the maximum development of students' capabilities. Through the application of pertinent methodologies related to participation, individual and/or collaborative, favoring critical and rational thinking, by carrying out reading and research activities. In this regard, Brito et al. (2019) states that: "it contributes from two areas: the cognitive related to intellectual development and the formative-axiological, related to personality development" (p. 304). For this reason, the use and management of educational laboratories is recommended. In order to strengthen the quality of education, mainly in the acquisition and strengthening of scientific skills in students.

It should be mentioned that the teacher's job is to guide the learning process using different methodologies and teaching strategies in the classroom. In this way, the student constructs his own knowledge individually and/or collaboratively. In this study, experimentation is



[Licencia Creative Commons Atribución 4.0 Internacional \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/)

used as a didactic strategy where the student analyzes the phenomena directly. In addition, Cueto and García (2017), indicate that: "significant learning occurs. Students, who already have some previous theoretical knowledge, will be able to relate practice with theory" (p. 48).

Currently, at the experimental level, traditional methodologies are applied, as is the case of experimental practices. For this type of practice, the use of laboratory guides is used. During this process, a certain cognitive stagnation is perceived in the students, due to the fact that all the information is provided in this document. Therefore, the student does not make an effort to reflect, investigate, or get involved in constructing his own knowledge. This problem has been pointed out by Llorente, (2016) in his article, where he examines the impact of experimental practices on student learning and motivation. Although, he highlights that experimental practices can motivate and generate good learning outcomes, he also warns about the need to move towards more challenging approaches. His study concludes that consecutive application of experimental practices can slow down cognitive development. In addition to limiting students' ability to reflect, investigate and actively participate in the construction of their own knowledge.

In view of this problem, a non-experimental research, with correlational scope, was carried out to study the teaching-learning process. The open research methodology was used through the planning and elaboration of a relevant model in the laboratory practices, called road map. The study was carried out on high school students of the "Nuestra Familia" Educational Unit. Thus, the present study proposes to analyze open research in laboratory practice and its relationship with the learning of chemistry. Considering Stoichiometry as the main axis of learning at all high school levels. For which we wish to determine the influence of the open laboratory practice in order to identify the process of open research.

The relevance of this study lies in the fact that, upon performing an exhaustive search in local and national databases, no similar research was found where the independent variable of this study, i.e., open research in laboratory practice, is considered. However, we did find degree works where experimental practices are employed with the use of a laboratory guide as a didactic tool. Therefore, this study is useful to expand and update the data on the learning of chemistry. As well as, proposals to improve the educational quality and the teaching-learning system in Ecuador.

This study faces several difficulties and challenges that may affect the interpretation of the results and the generalization of the conclusions. First, the implementation of open-ended research in laboratory practice may encounter lack of familiarity among students, which could influence the effectiveness of the proposed methodology. Finally, the difficulty in controlling all external variables that could influence the teaching-learning process may affect the internal validity of the study. Despite these challenges, addressing these difficulties will provide a solid foundation for future research, and improvements in the implementation of open-ended research in the educational context of Chemistry.

Despite the ambitious objectives and identified relevance, this study faces certain limits that must be considered when interpreting its results. First, there is the geographical and educational level limitation that could affect the generalization of the findings to other educational institutions or academic levels. Also, the selection of stoichiometry as the main focus of learning may limit the applicability of the results to other branches of chemistry. Finally, the study does not address external factors, such as socioeconomic or cultural conditions of the students, which could influence the results. These limits offer opportunities for future research that could expand and contextualize the findings of the



[Licencia Creative Commons Atribución 4.0 Internacional \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/)

present study. The present paper is articulated within the research line "Education, science, technology and innovation" and summarizes the most important elements and considerations that were fully developed in the thesis work of (Faican-Juca, 2023).

This article follows a clear and systematic organization, beginning with a literature review that establishes the context and grounds the research. It then details the methodology employed in the study, providing a description of the procedures used to obtain meaningful data. The results derived from the execution of the data collection instruments are presented in a comprehensive manner, followed by a discussion. Finally, the article concludes with a section summarizing the main contributions and conclusions drawn from the study.

2. Bibliographic review

2.1 Teaching and learning of chemistry

Currently, Garcés et al. point out that the teaching and learning of chemistry continues to be a complex process. It not only consists of the acquisition of theoretical knowledge, it also aims to acquire and strengthen skills, abilities and competencies in the student body (Garcés et al., 2018, p. 231-345). These being critical thinking, problem solving, cognitive and communication skills, ability to formulate hypotheses, experimentation and interpretation, among others. For this reason, Rodriguez and Cruz state that "it is crucial that a teacher possesses not only a deep knowledge of the subject he or she teaches, but also solid pedagogical skills" (Rodriguez and Cruz, 2020, p. 1). "The ability to communicate complex concepts, motivate students and evaluate their progress are essential aspects that derive from a pedagogical training, thus contributing to a more comprehensive and meaningful education" (Lorduy and Naranjo, 2020; Martínez et al., 2018).

2.2 Experimentation as a didactic strategy

According to Neira, through experimentation, the teacher optimizes and strengthens meaningful learning. While, with the planning and pertinent design of laboratory practices, the acquisition of new knowledge and its relationship with previous knowledge is guaranteed (Neira, 2021). In this way, experimentation is an effective strategy by providing students with ideal moments for learning and strengthening their autonomy and curiosity. As Molina et al. (2018) verify by stating that:

The teacher determines to a great extent the attitudes of the students and their performance in a course, the way he/she conducts the course and the use of didactic methodologies can generate a better or worse training (p. 54)

As shown in Figure 1, Hernández discusses that the methodology applied in theoretical and experimental teaching differs in the intervention and action of the students, therefore, there is also a difference in the cognitive process to be developed. During a theoretical teaching, the student is indirectly involved with the phenomenon given and explained by the teacher, producing a passive and receptive learning. This implies a low cognitive process related to the acquisition of knowledge. Hernandez also emphasizes that, in experiential teaching, the student has a direct participation in the learning process. Because cognitive processes such as observation, analysis, deduction among others are involved, provoking interest, curiosity and inquiry (Hernández, 2013, p. 86-108).



[Licencia Creative Commons Atribución 4.0 Internacional \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/)

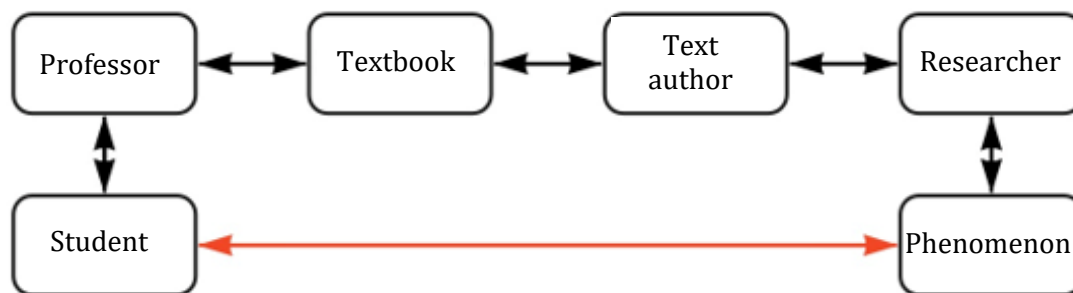


Figure 1. Comparison between theoretical and experimental teaching. Taken from: (Hernández, 2013, p. 92). Note: The figure represents the relationship between theoretical teaching (black arrows) and experimental teaching (red arrow).

2.3 Laboratory practices

The work done in the laboratory is essential, therefore, different methodological strategies should be used in the planning of the class (Rodríguez, 2017). There is a great variety of types of laboratory practices, which have been classified by Herrón 1971 and by Priestley 1997. These two authors proposed a scale of five and seven levels of openness respectively (Neira et al., 2021). "The levels of openness are based on the roles of the student and the teacher, when the role of the student is greater in the learning process the level of openness is high" (Cueto and Garcia, 2017; Zorrilla et al., 2020). The most commonly used laboratory practices are:

- Demonstrative practices. Valverde states that in this type of practice the student acts as observer and receiver, and the teacher is in charge of the whole experimental process. Both the objective, material, method and solution are given, so it is at the first level of openness and the cognitive process developed is knowledge acquisition (Valverde et al., 2006, p. 62).
- Experimental practices: according to Llorente, in these practices, the teacher develops a laboratory guide and the student is in charge of the execution following the given procedure, in these practices the objective, material and method are given completely, as for the solution it can be delivered in part. It is considered as second or third level of opening, developing knowledge and understanding as a cognitive process (Llorente, 2016, p. 8-9).
- - Open inquiry practices: Zorrilla focuses on the scale proposed by Herrón, open inquiry practices are distinguished by adopting an investigative approach, where the teacher establishes the objective, and the student assumes the responsibility of exploring the materials, methods and possible solutions to address the proposed problem (Zorrilla, 2018, p. 34). In Priestley's taxonomy, this type of practice is placed at level 6, characterized by the assignment of the problem by the teacher. While the student is in charge of developing the appropriate procedure and reaching their own conclusions. Both classifications highlight the ability of open inquiry practices to actively involve the student in the learning process. In addition to fostering high-impact cognitive processes, such as analysis and synthesis. This is confirmed by Jiménez, who indicates that this approach not only promotes the acquisition of knowledge, but also stimulates critical thinking and intellectual autonomy of the student. Finally, it contributes to deeper and more meaningful learning (Jiménez et al., 2005, p. 9).



[Licencia Creative Commons Atribución 4.0 Internacional \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/)

Laboratory practices are fundamental for the scientific and comprehensive training of students by employing different processes and complying with basic work standards, as explained by (Hernández et al., 2018):

with the approach of the experiment to the research activity, as well as the requirements for management, constitute the foundations on which the didactic procedures for the contribution to scientific training from laboratory practices are based (p. 325).

3. Methodology

This research presented a non-experimental design because it dispensed with the intentional manipulation of variables. "It seeks to understand the intrinsic dynamics of the phenomena, providing valuable information about their nature and causal relationships without disturbing their natural course" (Monje, 2011, p. 26). Its approach "was quantitative and correlational in scope where it was determined as an independent variable, open research in laboratory practice, for being manipulable and modifiable in the research process" (Hernández et al., 2014). As a dependent variable, the learning of chemistry, as it is the one whose behavior is affected by the previous variable. The primary purpose was to analyze whether open research in laboratory practice is related to the learning of chemistry, this being the hypothesis put forward. For which, we worked with 125 high school students of the Unidad Educativa Nuestra Familia, "no sampling was applied, because it was a small population" (Paniagua and Condori, 2018, p. 45).

For the open investigation in the laboratory practice, the following phases were followed:

- Planning phase, the teacher prepared a document detailing the problem and the objective to be achieved, called a roadmap. In this document, a contextualized problem based on stoichiometry was included, in addition to specifying the activities to be carried out during the pre-laboratory, laboratory and post-laboratory phases.
 - Execution phase, the student's work was divided into three parts:
 - Pre-laboratory which consists of the research process, this is the first part where students inquired aspects about the use and employment of reagents, materials, procedure to be applied, adequate and relevant chemical methods, analytical calculations and safety standards to meet the objective and solve the problem posed. Laboratory is the second part, which consisted of the execution of the practice, complying with the previous research and constant teaching support.
 - Post-laboratory is the last part, where students were responsible for preparing and presenting the corresponding report, in addition to completing the questionnaire and *Google Forms test*.

3.1 Research techniques and instruments

For data collection, two techniques were applied with their respective instruments, which were previously validated by professional experts and statistically tested in a pilot population. Cronbach's Alpha Coefficient was calculated, where a reliability of 0.8008 was obtained, which was subsequently interpreted with the scale described in the work of (Supo, 2013). The result presented a significant reliability range. Therefore, the instruments applied to the study population of "Nuestra Familia" were duly validated and reliable. The first technique applied was the survey by means of a questionnaire as an instrument, the same one elaborated in the Google Forms program. The students received the invitation



[Licencia Creative Commons Atribución 4.0 Internacional \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/)

through the Classroom platform and responded online, individually, voluntarily and anonymously. This form contained a total of 15 questions for the two variables. Eight questions were posed with more than one answer option. They were aimed at investigating the application, didactics and frequency of laboratory practices, as well as the roles of teachers and students. These questions allowed collecting data for the independent variable (open investigation in laboratory practice). On the other hand, for the dependent variable (learning chemistry), five questions were posed. These addressed the relationship between previous knowledge and acquired knowledge, as well as the attainment of skills, abilities and competencies.

The second technique was the evaluation instrument using a diagnostic evaluation test. This test consisted of 10 questions generated through Google Forms and shared with the students by Classroom. It was used to determine the scale of learning obtained. Its questions were based on the work done in the laboratory such as use and function of materials and reagents. In addition, about physical-chemical processes and stoichiometric contents. The quantitative results of this test contributed to the dependent variable. That is to say, they allowed knowing and analyzing the learning of the students by using the scale of learning achieved (qualitative scale) governed in the educational institution.

3.2 Data processing and analysis techniques

For data processing, the results of the questions corresponding to the same dimension were grouped and the arithmetic mean was determined. Subsequently, these averages were taken to the statistical software Minitab Statistical 20, in which contingency tables were made with a greater representation. In addition, it was "determined the trends of the responses according to the frequencies obtained" (Hernández et al., 2014), To test whether the open-ended research in the laboratory practice is related to the learning of Chemistry. That is, for hypothesis testing, the normality test and a nonparametric measure such as *Spearman's coefficient* were performed.

4. Results

In order to specify the most relevant aspects in the development of laboratory practices, the types of practices used in the educational institution were analyzed. Table 1 shows the types of laboratory practices applied in the teaching of chemistry and their frequency. From the students' point of view, they state that the most used are experimental practices with 56.35%. Next are the demonstrative practices with 23.20% and finally the practices with open research with 20.44%. Regarding the cognitive contribution, the types of laboratory practice and their impact on the acquisition and understanding of knowledge were compared. According to the students' perspective, 44.27% indicated that experimental practices have a greater impact, 28.73% stated that demonstrative practices and 27.00% declared that practices with open research have a greater impact.



[Licencia Creative Commons Atribución 4.0 Internacional \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/)

Types of practices	Frequency	Cognitive contribution
Demostrative	23.20 %	28.73 %
Experimental	56.35 %	44.27 %
Open research	20.44 %	27.00 %
Total	100.00 %	100.00 %

Table 1. Types of laboratory practices and their characteristics

In Table 2, for the degree of complexity, 65.60% of students revealed a high level of complexity when performing practices with open research. They mainly indicated difficulty during the investigative and analytical phase (stoichiometric calculations). Analyzing the teaching support in this methodology, only 24.53% of students considered it to be optimal, constant and adequate in each phase of the process. Regarding the complexity when studying stoichiometry, considering that this is the axis of study, 64.80% of students indicated a minor or low complexity. On the other hand, 35.2% stated a high or higher complexity, in relation to the difficulty in understanding the problem posed and the analysis of the chemical reaction produced in the laboratory practice.

Level	Open research		Stoichiometry
	Complexity	Teacher support	Complexity
High	65.60 %	24.53 %	35.20 %
Low	34.40 %	75.47 %	64.80 %
Total	100.00 %	100.00 %	100.00 %

Table 2. Open research characteristics and stoichiometry complexity.

Table 3 reflects the students' perspective on the benefits derived from the intervention and application of open-ended research in laboratory practice. According to their evaluations, the collaborative approach of this methodology has contributed significantly to the development of key skills. Evidenced by outstanding percentages: 78.40 % in collaborative work, 76.80 % in organization, 68.00 % in problem solving and 65.60 % in analysis.



[Licencia Creative Commons Atribución 4.0 Internacional \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/)

Level	Skills			
	Analysis	Troubleshooting	Collaborative work	Organization
High	65.60 %	68.00 %	78.40 %	76.80 %
Low	34.40 %	32.00 %	21.60 %	23.20 %
Total	100 %	100 %	100 %	100 %

Table 3. Skills obtained

In Table 4, the data reveal that 74.40 % acquired a high level of experimentation, 68.80 % in observation, and 66.40 % in research, evidencing significant skills and competencies. These results suggest that the implementation of open inquiry has had a positive impact on strengthening essential skills for students. In comparison with other forms of laboratory practices, such as the demonstrative and/or experimental ones employed throughout their secondary education. These findings highlight the particular effectiveness of open inquiry in fostering fundamental skills, abilities, and competencies for scientific learning.

Level	Skills and competencies		
	Observation	Research	Experimentation
High	68.80 %	66.40 %	74.40 %
Low	31.20 %	33.60 %	25.60 %
Total	100 %	100 %	100 %

Table 4: Skills and competences obtained

The learning process was evaluated through the application of a test with 10 questions that collected information on the use of materials. Where 98.4%, 95.2% and 48% of students were correct in questions 1, 2, 3 respectively. Questions 4, 5, 6, 7 determined the understanding of physical-chemical processes, obtaining that 91.2%, 69.6%, 45.6% and 73.6% of students choose the correct answer for each question. Regarding stoichiometric calculations, for question 8, 49.6% got it right, for question 9, 84.8% got it right, and for the last question, 88% of students got it right.



[Licencia Creative Commons Atribución 4.0 Internacional \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/)

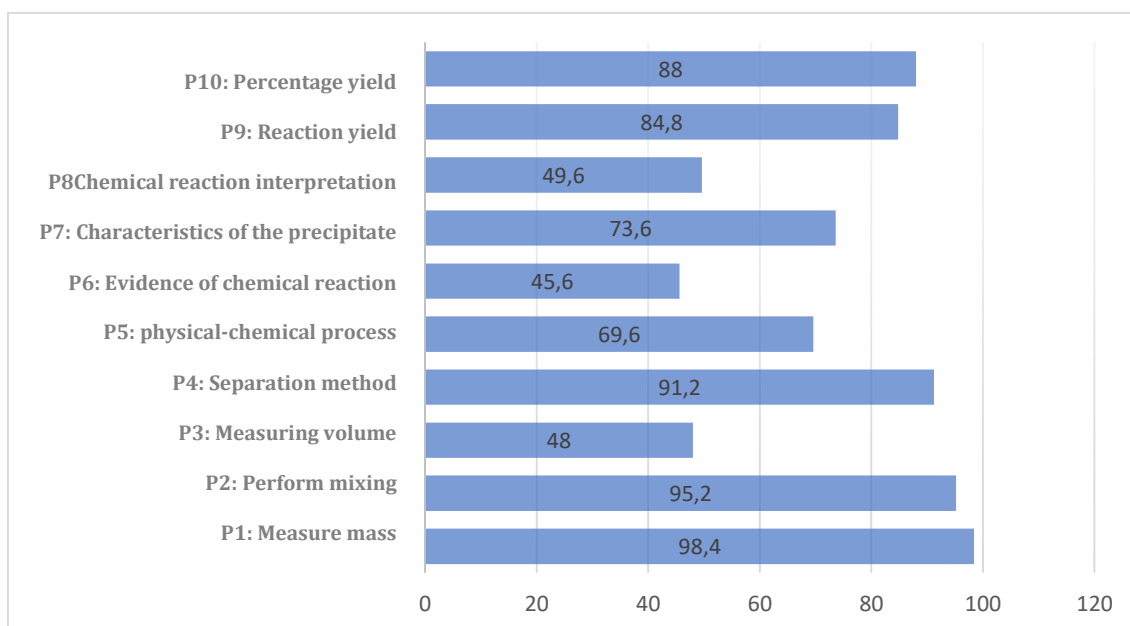


Figure 2. Percentage of correct answers by question

Each test had a final evaluation of 10 points and the scale of learning achieved was used. It was obtained that 28% of the students mastered the learning, because they obtained a score higher than 9/10. 47.20% of the students achieve the learning, whose valuation was between 8.99 and 7. Finally, 4.80% do not achieve the learning related to stoichiometry, as well as the correct use and function of materials and reagents, as shown in Table 5.

Scale of learning achieved	Range	Students	Percentage
Master the required learning	10 – 9.00	35	28.00 %
Achieving the required learning	8.99 – 7.00	59	47.20 %
Is close to achieving the required learning	6.99 – 4.01	25	20.00 %
Does not reach the required learning	4.00 – 0	6	4.80 %
Total		125	100.00 %

Table 5. Learning scale. Taken from: (Subsecretaría de Fundamentos Educativos, 2016, p. 8).

In order to test the study hypothesis, which consists of relating the open investigation in the laboratory practice with the learning of chemistry, the hypothesis test was performed. Considering that the variables were quantitative and discrete, which did not present a normal distribution in the normality test. The significance level was 95%. Therefore, a non-parametric measure was used and Spearman's correlation coefficient was calculated. A value of 0.550 was obtained for rho, as can be seen in the scatter diagram, Figure 3.



[Licencia Creative Commons Atribución 4.0 Internacional \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/)

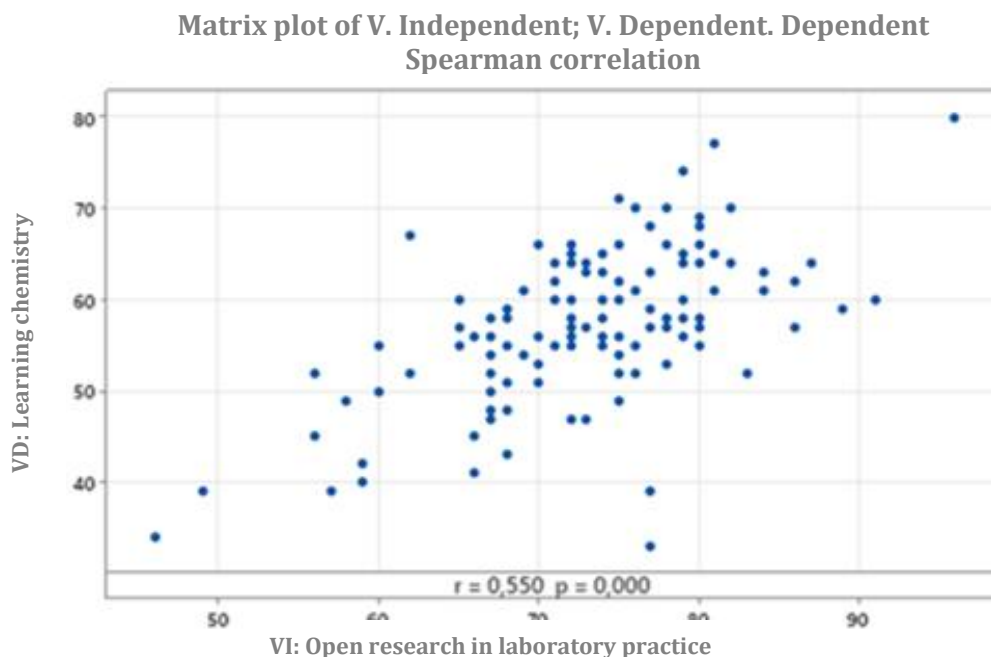


Figure 3. Spearman's correlation coefficient

Therefore, when performing the hypothesis test based on Spearman's correlation, it was determined that the open investigation in the laboratory practice is related to the learning of Chemistry. The interpretation of the rho value, as analyzed in Table 6, shows a positive, moderate, and significant relationship or association. By obtaining a rho value of 0.550, considering a level of significance of 0.05.

rho range	Interpretation
- 0.76 a - 1.00	Negative correlation between strong and perfect
- 0.51 a - 0.75	Negative correlation between moderate and strong
- 0.26 a - 0.50	Negative correlation between weak and weak
- 0.01 a - 0.25	Negative correlation between weak and null
0	Null correlation
+ 0.01 a + 0.25	Positive correlation between weak and null
+ 0.26 a + 0.50	Positive correlation between weak and weak
+ 0.51 a + 0.75	Positive correlation between moderate and strong
+ 0.76 a + 1.00	Positive correlation between strong and perfect

Table 6. Interpretation of Spearman's correlation. Adapted from: (Roy et al., 2019).

- Positive correlation whose meaning lies in the fact that the learning of chemistry increases as the application of open-ended research increases.
- Moderate correlation means a moderate strength of association between the variables by obtaining a value of 0.550.
- Significant correlation when generalizing these results to other study populations.



[Licencia Creative Commons Atribución 4.0 Internacional \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/)

5. Discussion

The results derived from the investigation, Figure 3, determined a positive, moderate and significant association between the independent variables "open investigation in laboratory practice" and the dependent variable "learning Chemistry". From Spearman's correlation test, it is inferred that Chemistry learning is related to laboratory practice using open-ended inquiry. According to the rho value of 0.550 which shows a positive association. This result is corroborated with the study conducted by (Villanueva and Concha, 2020), in which it demonstrates the importance of research in the experimental process. Although this methodology has a moderate relationship with respect to learning, it should be considered that there are other factors that prevent increasing this relationship since it does not depend only on practice.

Experimentation with open research has a positive influence on the learning of high school students, as shown in Table 1. However, 44.27 % of students still prefer traditional practices, considering that the student is immersed in this paradigm where all information is given to him/her in full. This result has been verified by Zorrilla et al., 2020 in their doctoral thesis, where they indicate that the most developed experimental classes correspond to low levels of openness. In these practices the student requires basic cognitive processes, such as knowledge, application. Consequently, the student feels more comfortable with traditional practices. Whereas, in open inquiry practices, it generates a higher level cognitive development, because the student is fully involved in the process of research and experimentation.

The teacher's action is considerably reduced, as shown in the analysis of Table 2. That is why 24.53% of students indicate having obtained optimal support from the teacher throughout the experimentation process. For a significant acquisition in relation to learning, the student must demonstrate basic knowledge of experimentation. This is corroborated by the result, where 65.60% of participants consider that open research presents a higher degree of difficulty in its execution and is preferred by only 27% of the students. These results are supported by the study of Llorente, 2016 where he recommends open research practices for a greater scope in learning, considering the predisposition of the student. Likewise, Cueto and García, 2017 demonstrated through their thesis the effectiveness of research-based methodologies, even indicating that it facilitates learning and improves achievement.

It should be emphasized that, these results differ with those obtained in Table 3 and 4, where an optimal contribution of open inquiry is identified. By producing in students the acquisition of skills, competencies and abilities. It was obtained that more than 65.60% of the students acquired and strengthened skills such as: collaborative work, organization, problem solving and analysis. Likewise, more than 66.40% acquired a high level of experimentation, observation and research as skills. However, certain important aspects should be considered, such as: teacher support, proper planning and elaboration of the road map by the teacher, as well as research in reliable sources and equitable work, complying with safety standards. Coinciding with the research of Hernandez et al., 2018 that proved that, when considering the levels of openness in laboratory practices provide exceptional and high-level results, for the scientific and academic training of students. In this study, it was found that the level of openness, open research in laboratory practice positively influences and contributes to the learning of Chemistry.

In Table 5, the results when evaluating the learning of stoichiometry applying the learning scale achieved, given by the Ministry of Education. Favorable results were obtained,



[Licencia Creative Commons Atribución 4.0 Internacional \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/)

indicating that 75% of the students reached and/or mastered the learning, by obtaining a grade higher than 7/10. Considering that the questions addressed stoichiometric contents, differentiation of physical-chemical processes and the appropriate use of laboratory materials. This result contrasts with the study of Raviolo and Lerzo, 2016, where it is indicated that, in order to guarantee the understanding of stoichiometry, and therefore the obtaining of optimal evaluative results, it is necessary to develop experimental methods for its teaching.

6. Conclusion

From the results obtained in this research, it is concluded that a positive influence was determined between open research in laboratory practice and the learning of chemistry, by presenting a moderate and positive relationship between the application of open research and learning, although only 27% of students considered that open research has a high cognitive contribution in the process. It should be emphasized that a considerable contribution to learning was identified, since open research intervenes in the acquisition of abilities and skills and competences with a percentage of 73.60% and 69.60% in the students, respectively. In addition, the process was evaluated through the application of a test, as a result it was obtained that 28% of students master the required learning and 47% reach the learning, these values indicate a learning of Chemistry mainly of stoichiometry. Finally, it was established that there is a considerable percentage of students, 44.27%, who still prefer traditional laboratory practices mainly using laboratory guides.

In the course of the research, factors that impede the practice of open research were identified, the main one being the educational curriculum, including the temporality and frequency of its application. For future lines of research, it is recommended to carry out studies that analyze the application of open inquiry in laboratory practice, considering the use of materials and reagents of daily or home use. Also, to study the influence of open inquiry in the laboratory and STEAM projects.

Bibliographic references

- Brito, D., Maldonado, L., y Morillo, R. (2019). Nivel Bachillerato. En *Currículo de los Niveles de Educación Obligatoria*. (Segunda, pp. 295-335). www.educacion.gob.ec
- Cueto, R., y García, C. (2017). *Física y Química en el aula, el aprendizaje a través de la práctica* [Tesis de Máster en Formación del Profesorado de Educación Secundaria]. Universidad de Cantabria.
- Faicán, F. (2023). *Investigación abierta en la práctica de laboratorio y el aprendizaje de la Química en los estudiantes de Bachillerato de la Unidad Educativa "Nuestra Familia" periodo 2021-2022* [Tesis de Magister en Pedagogía de las Ciencias Experimentales Mención Química y Biología]. Universidad Central del Ecuador.
- Garcés, L., Montaluisa, Á., y Salas, E. (2018). El aprendizaje significativo y su relación con los estilos de aprendizaje. *Anales de la Universidad Central del Ecuador*, 1(376), 231-245.
- Hernández, L., Machado, E., Martínez, E., Andreu, N., y Flint, A. (2018). La práctica de laboratorio en la asignatura Química General y su enfoque investigativo. *Rev. Cubana Quím*, 30(2), 314-327.
- Hernández, M. (2013). Reforma de la enseñanza experimental. En *Enseñanza experimental Química* (Primera edición, pp. 86-108). Universidad Nacional Autónoma de México.



[Licencia Creative Commons Atribución 4.0 Internacional \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/)

- Hernández, R., Fernández, C., y Baptista, M. (2014). Definiciones de los enfoques cuantitativo y cualitativo, sus similitudes y diferencias. En *Metodología de la Investigación* (Sexta, pp. 88-100). McGRAW-HILL.
- Jiménez, G., Llobera, R., y Llitjós, A. (2005). Los niveles de abertura en las prácticas cooperativas de química. *Revista Electrónica de Enseñanza de las Ciencias*, 4, 4-26.
- Llorente, P. (2016). *Efecto de las prácticas experimentales en el aprendizaje y motivación de los alumnos para la asignatura de química de primer curso de Bachillerato* [Tesis de Máster en Formación de profesorado de Secundaria - Especialidad Física y Química]. Universidad Internacional de la Rioja.
- Lorduy, D. J., y Naranjo, C. P. (2020). Percepciones de maestros y estudiantes sobre el uso del triplete químico en los procesos de enseñanza-aprendizaje. *Revista Científica CIDC*, 39(3), 324-340. <https://doi.org/10.14483/23448350.16427>
- Martínez, L. D., Hinojo, F. J., y Díaz, I. (2018). Aplicación de las Tecnologías de la Información y la Comunicación (TIC) en los Procesos de Enseñanza- Aprendizaje por parte de los Profesores de Química. *Información tecnológica*, 29(2), 41-52. <https://doi.org/10.4067/s0718-07642018000200041>
- Molina, M. F., Rivera, J. C., Liliam, y Palomeque-F, A. (2018). Actitudes y perspectivas de los estudiantes frente a un curso de química general: implicaciones y propuestas. *Revista Educación en Ingeniería*, 14(27), 54-58. <https://doi.org/10.26507/rei.v14n27.931>
- Monje, C. (2011). *Metodología de la Investigación Cuantitativa y Cualitativa*.
- Neira, J. (2021). La experimentación en ciencias naturales como estrategia de alfabetización científica. *Revista UCMaule*, 60, 102-116. <https://doi.org/10.29035/ucmaule.60.102>
- Neira, J. C., Miño, L. P., y Fuentealba, M. I. (2021). Aproximación a las dificultades para la ejecución de trabajos prácticos de laboratorio de biología en educación media. *Revista Convergencia Educativa*, 10-extra, 24-33. <https://doi.org/10.29035/rce.s10.24>
- Paniagua, F., y Condori, P. (2018). *Investigación científica en educación* (Porfirio Condori Ojeda, Ed.; Segunda).
- Raviolo, A., y Lerzo, G. (2016). Enseñanza de la estequiometría: Uso de analogías y comprensión conceptual. *Educación Química*, 27(3), 195-204. <https://doi.org/10.1016/j.eq.2016.04.003>
- Rodríguez, R. (2017). *El aprendizaje significativo de conceptos químicos, un estudio en el contexto de la resolución de problemas y los estilos de aprendizaje* [Tesis Doctoral en Educación]. Universidad Pedagógica Nacional.
- Roy, I., Rivas, R., Pérez, M., y Palacios, L. (2019). Correlación: no toda correlación implica causalidad. *Revista Alergia México*, 66(3), 354-360. <https://doi.org/10.29262/ram.v66i3.651>
- Subsecretaría de Fundamentos Educativos. (2016). *INSTRUCTIVO PARA LA APLICACIÓN DE LA EVALUACIÓN ESTUDIANTIL*.
- Supo, D. J. (2013). *Cómo validar un instrumento*. www.bioestadistico.com



[Licencia Creative Commons Atribución 4.0 Internacional \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/)

- Valverde, J., Jiménez, L., y Viza, L. (2006). La atención a la diversidad en las prácticas en las prácticas de laboratorio de Química: Los niveles de abertura. *Enseñanza de las Ciencias*, 24(1), 59-70.
- Villanueva, M., y Concha, A. (2020). Laboratorio de química: indagación guiada. *EDUNOVATIC*, 305. www.edunovatic.org
- Zorrilla, E. (2018). *Las prácticas de laboratorio en la enseñanza y el aprendizaje de las Ciencias Naturales desde una perspectiva psicosocial* [Tesis de Doctorado en Educación]. Universidad Nacional de Cuyo.
- Zorrilla, E., Quiroga, D. P., Morales, L. M., Mazzitelli, C. A., y Maturano, C. I. (2020). Reflexión sobre el trabajo experimental planteado como investigación con docentes de Ciencias Naturales. *Ciencia, Docencia y Tecnología*, 31(60 may-oct), 266-285. <https://doi.org/10.33255/3160/626>

Authors

FERNANDA FAICÁN-JUCA obtained her master's degree in Pedagogy of Experimental Sciences mention in Chemistry and Biology from the Universidad Central del Ecuador in 2023. She obtained her degree in Pharmaceutical Biochemistry from the Faculty of Chemical Sciences at the University of Cuenca (Ecuador) in 2017.

She is currently a tenured teacher at Unidad Educativa Nuestra Familia. She is a leading teacher in institutional projects such as "Formando científicos" and "Primeros Auxilios NF". Her main research topics include application of innovative methodologies at the level of laboratory practices, focusing specifically on chemistry learning.

RENATO MANZANO-VELA He obtained his degree in Chemical Engineering from the Escuela Superior Politécnica de Chimborazo-Ecuador, Master in Chemistry with mention in Chemistry-Physics from the Universidad Técnica de Ambato-Ecuador, Master in Pedagogy with mention in curriculum from the Universidad Técnica del Norte-Ecuador, PhD Candidate in the Doctoral Program in Chemistry at the University of Granada-Spain, Fellow in the Master Molecular Simulation at the International University of Andalusia-Spain, Master in the Master in Biotechnology at the State University of Milagro-Ecuador. Fellow in the Master's program in Pedagogy with mention in Curriculum at the Universidad Técnica del Norte-Ecuador, Master and Fellow in the Master's program in Management of Sanitary Programs in Food Safety at the University for International Cooperation-Costa Rica. Fellow as a participating member of the IX School of Experimental Physics of the Universidad Autónoma de México. Evaluator in the science and entrepreneurship competitions INFOMATRIX 2020, 2022 2023 and 100K LATAM.

Member of committee E01 on Analytical Chemistry of Metals, Minerals and Related Materials in ASTM International. Researcher registered in SENESCYT. Teacher in the Coordination of Admission and Leveling of the National University of Chimborazo, Teacher and tutor in the Master's program in Pedagogy of Experimental Sciences mention in Chemistry and Biology offered by the Central University of Ecuador, Teacher in the Faculty of Health of the Regional University of the Andes, Researcher Teacher in the Faculty of Natural Resources of the Polytechnic School of Chimborazo. Author and co-author of 20 scientific articles, 3 books and a book chapter in international publishers.



[Licencia Creative Commons Atribución 4.0 Internacional \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/)