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Experimentation and its Impact on Chemistry Learning in Virtual and Face-to-Face Environments after the Covid 19 Pandemic

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Abstract

The COVID-19 pandemic in the educational system generated changes in methodologies, strategies, and didactic resources in the development of the teaching-learning process of Chemistry. For this purpose, simulators and virtual laboratories were used as resources linked to learning during the Covid-19 pandemic; after the face-to-face activities, experimental activities in the laboratory were resumed. The research was quasi-experimental with a correlational level and analyzes the incidence of the virtual and physical environment in the learning of General Chemistry, determining that the face-to-face experimental activities have a significant impact on the development of cognitive and procedural skills of students compared to virtual learning with simulators.

Keywords: *Learning, experimentation, laboratory, simulator.*

INTRODUCTION

The learning of Chemistry involves "a set of systematic transformations in individuals after a series of experimental activities to link theory with practice" (Hernández & Benítez, 2018:8), being a progressive, dynamic and transformative process that generates successive and uninterrupted changes in the student's cognitive activity. Generally, experiential activities are educational actions that promote experiences in a certain context, which are carried out by the student and/or the teacher in a cooperative manner; To this end, using materials, laboratory reagents and materials from their environment aimed at articulating theory and practice in the teaching-learning process, where the verification of their theoretical foundations, the observation and interpretation of chemical principles, are vital for the logical and interpretative reasoning of this science.

Due to the worldwide confinement caused by the COVID-19 pandemic, all levels of education in the world adopted the virtual modality, and given the impossibility of going to the laboratory, the teaching-learning process of Chemistry had to take relevant turns around the use of virtual environments, with the purpose of promoting a cognitive structure in students. Teachers were forced to develop new forms of teaching strategies "based on

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ubiquitous, instantaneous, and sustained communication and collaboration in real time, which in ancient times was unthinkable" (Crespo & Palaguachi 2020: 295).

The National University of Chimborazo, especially the Career of Pedagogy of Experimental Sciences, Chemistry and Biology, in the face of the global problem, sought new learning environments, proposing the use of simulators and virtual laboratories in the educational teaching process to strengthen the pedagogical action of the teacher in the area of Chemistry and apply new forms of teaching that allow meeting the proposed objectives despite the limitations due to the pandemic of COVID-19 until the 2022-1S academic year. Already in the 2022-2s academic period, face-to-face learning is returned, resuming experimental activities in institutional laboratories "where manipulation, interaction with people build knowledge, activate their cognitive schemes through the process of assimilation and accommodation; where successive experiences of accommodation give rise to novel assimilation schemes, thus reaching a new state of equilibrium (Raynaudo & Peralta 2017:142). All of this is aimed at developing a dynamic, progressive and transformative process for the meaningful learning of Chemistry.

Learning General Chemistry

Experimentation in the educational field is a didactic strategy that consists of studying a phenomenon, reproducing it under certain attractive study conditions, omitting or introducing variables that may affect a study phenomenon.

According to (Zambrano, 2018), experimentation is divided into several phases of knowledge internalization:

- Observation: The starting point is always a physical fact or phenomenon that science tries to explain and with the collection of characteristics of it.

- Hypothesis formulation: The facts themselves say nothing. The next phase, therefore, is to formulate hypotheses, or possible explanations that link these factors to each other.

- Contrast: Consists of experiments, which are the means necessary to confirm a hypothesis or reject a hypothesis. Experiments should be conducted to ensure that the hypothesis holds true not only in the initial case, but also in new cases.

- Control: Therefore, experiments are a means of confirming or refuting hypotheses. Depending on the outcome of the experiment, the hypothesis is accepted or rejected (validation). If the hypothesis is proven, it is accepted as a law of nature (at least until it is refuted by new experiments).

- Expression of conclusions: It is based on the results obtained in the experimental process and is supported by scientific content.

Experimental activity is usually used to test certain hypotheses about something, generally this research is carried out in a laboratory or a space is adapted for it. Once a hypothesis has been formulated, the researcher must verify if it is real, if it is true, for this an infinite number of experiments must be put into practice, changing the variables that participate in the process and thus be able to verify if it is true.

Experimentation as a didactic strategy for the learning of Chemistry, prioritizes meaningful learning in a dynamic and applicable way, is proposed as an entity of transformation in the educational process, involves many individual activities and is mainly related to the recognition and application of laws.

Experimentation is based on putting students in direct contact with an unknown, known or partially known phenomenon that produces it and promotes it to be reproduced, with the purpose of analyzing, understanding, mastering and using it. This strategy requires the comprehensive intervention of the student and allows him to verify the knowledge acquired, especially in the Experimental Sciences, develop a scientific-critical mindset and highlight the notion of cause and effect of phenomena (Gómez A., 2019). The planning of the activities provides a suitable environment, an orderly procedure and accurate results for the analysis of contents in General Chemistry.

Laboratory practice is a powerful pedagogical strategy for the construction of conceptual, procedural and even attitudinal skills. In times of pandemic, the tools available on the web, such as simulators and virtual laboratories with their theoretical models, have been considered as computer tools that allow the development of numerical calculations and the generation of visual representations of different phenomena or situations provided by ICTs and simulate a chemical testing laboratory from a virtual environment. Of course, they are limited in the teaching of certain aspects related to the "experimental practice of chemistry, but at the same time they have virtues that offer more plasticity than a real laboratory in the teaching of this science" (Torres 2017:9).

A virtual lab is considered a computer simulation of a wide variety of situations in an interactive environment; That is, you can simulate the behavior of a certain system that you want to study using mathematical models, and although you do not interact with real processes or systems, experimentation with simulated models is comparable to reality, as long as these models are realistic and represent important details of the system to be analyzed, in addition to the graphs that represent the temporal evolution of the system are complemented with animations that make it possible to see and see the system. better understand the behavior of the process (Velasco, Martínez & Velasco 2013:1).

Others define it as experimental learning spaces that simulate conditions close to reality since it allows the development of "laboratory practices through a menu located in the toolbar, like a text editor, in which equipment is available according to the needs of the practices and instructions executed by the operator through a computer" (Acosta 2019:29).

The use of interactive simulations "used in education are virtual environments that allow the visualization and exploration of phenomena, where students manipulate variables using different controls, and receive feedback on the effect of that manipulation immediately through an animation" (López 2020:2), "constituting catalysts, which transform and modify current learning scenarios, promoting motivation and dynamizing the teaching-learning processes that are linked to the requirements of the knowledge society" (Flores & Garrido 2019: 46).

In view of the fact that simulations allow experiences to be reproduced (multiple times), which may require a costly time, time and assembly, sometimes complicated to handle, they allow to corroborate predictions that students make before interacting with the tool, "building knowledge on the basis of discussion and comparison of results, allows students to relate the experience to their reality and propose possible applications, suggests that it is a great alternative when it comes to teaching" (Mendoza 2017:98).

In order for the education system to obtain successful results by implementing all kinds of technological tools, in particular virtual simulators, it is the fundamental task of teachers to appropriate and use these new strategies in the classroom, which help to favor cognitive development, interaction between students, and the predisposition for them to learn and optimize their learning through the advantages presented by the world of simulation virtual. (Carrión, García & Erazo 2020: 212)

The teaching-learning process of Chemistry is not easy, so it is necessary that in the face-to-face classroom, teachers use the laboratory as a didactic resource for the educational teaching process, which allows them to achieve the planned learning results, and this experimental activity confronts the reality of the phenomena studied that lead to the appropriation of scientific knowledge in a critical and reflective way.

METHODOLOGY

The research was carried out at the National University of Chimborazo, Faculty of Educational, Human Sciences and Technology, in the Career of Pedagogy of Experimental Sciences, Chemistry and Biology. In the 2022-1s virtual modalities with 43 students; 2022-2s with face-to-face modality: 32 students enrolled in the second semester in the Chair of General Chemistry in the aforementioned periods.

The study was mainly quantitative in nature because it is characterized by numerical data, it is of a basic type with an explanatory level, because it will answer the research question: is there any significant difference in the learning of chemistry in the virtual and physical laboratory. In a first phase, experimental activities were developed in a virtual environment and in the laboratory with topics related to: Properties, changes and measurement of matter; bonding and chemical compounds.

The second phase consisted of the application of an online survey designed to obtain an assessment of the students' perception in relation to the cognitive and procedural aspects of the execution of the experimental activities achieved with the application of the Crocodile Chemistry 605 and PhET virtual laboratories, as well as within the laboratory.

In each phase, the consent and support of the students was obtained. As an instrument for data collection, a questionnaire was used to determine the satisfaction of the use of the learning environments and the laboratory and test reports. The questionnaire was applied using the Google Forms tool, consisting of 9 selection questions using the Likert Scale with 5 levels (Totally agree, agree, indifferent, disagree and strongly disagree) to the study population related to cognitive and procedural aspects acquired in the process.

The analysis of the data was carried out with the academic performance of the students, once the experimental practices were applied, the grading scale is described in Table 1.

Table 1. Grading Scale Variable Academic Performance

Rating Scale		Equivalence-description
AAR	7-10	Achieve the required learning
PAAR	4.01-6.99	To achieve the required learning requirements
NAAR	0-4	Does not reach the required learning requirements

Source: Authors' own creation

The data obtained were also subjected to a statistical analysis process that was freely accessible in Python, Rstudio and SPSS software. The method applied to obtain the results was heuristic, assuming Ausubel's theory of meaningful learning, whose didactic sequence was based on this theory, which helped to understand the teaching-learning processes that involve three pedagogical moments: Initial problematization; Organization of Knowledge, and Application of Knowledge" (Muenchen & Delizoicov 2014: 620).

The first pedagogical moment is the initial problematization: they present real questions or situations that students know and witness and that are involved in the topics, issues that are not limited to guiding questions, which require students to only memorize and reproduce the knowledge. In this pedagogical moment, students are challenged to explain what they know about situations, so that the teacher can know what they think. The second pedagogical moment is the Organization of Knowledge, where, under the guidance of the teacher, the scientific knowledge necessary to understand the topics and the initial problematization are studied. The teacher will use various activities and methodological instruments, such as: exposition, formulation of questions, texts for discussions, extra-class work, experiences, among others. And finally, the third pedagogical moment was the application of knowledge, a moment destined to systematically address the knowledge incorporated by the student, to analyze and interpret both the initial situations that determined its study and others that, although not directly linked to the initial moment, can be understood by the same knowledge.

RESULTS AND DISCUSSION

Before applying the instruments for data collection, the reliability of the instrument was verified, the calculation was carried out using Cronbach's alpha coefficient. Table 2 shows the Alpha Coefficient with the observed score (raw_alpha:), corresponding to a value of 0.9358 which is close to 1, this indicates greater internal consistency of the instrument. Guttman's Lambda 6 (G6(smc)) is another measure of reliability, as is Alpha, in this case the value corresponds to 0.9578 and is also close to 1, so the instrument is considered reliable to be applied.

Table 2. Instrument Reliability (Survey)

Raw Alpha	std.alpha	GS(smc)
0.9358	0.9386	0.9578

Source: Survey Data

After verifying the reliability of the instrument, the survey was applied using Google forms, and the degree of acceptance of the planned experimental activities was measured, the results of which were subjected to a statistical analysis process with the Python software package. A total of 77 responses were received, and in order to carry out the analysis of the acceptance of the planned experimental activities, they were classified into two indicators: conceptual and experimental.

In reference to the conceptual indicator, 62.5% of the students totally agree that the use of simulators motivated the development of skills, 46.9% encouraged the development of strategies to solve theoretical and practical problems, 53.1% made them an active agent in the educational process, with individualized learning experiences, 59.4% promoted a learning environment with meaningful experiences. relevant and constant feedback. Finally, 56.3% strongly agree that the use of simulators allowed the learning outcomes proposed in the syllabus of the subject to be achieved.

According to the procedural indicator presented, 46.9% strongly agree that, through simulation, the resources, means and conditions proposed in the experimental activities are visualized. 56.3% of the respondents process the information obtained in the simulation by contrasting the results with the theory. 53.1% interpret the results obtained in each activity. Likewise, 59.4% of the students interpret the results obtained in each activity through the use of the simulator

Descriptive analysis of students' academic performance

The grades of the students of the teaching, experimental and autonomous practice components are available, the same that were obtained after having applied the activities in virtual and face-to-face environments, specifically for the experimental practical component, virtual resources such as: PhET and Crocodile_Chemistry605 were used. We are interested in evaluating the effectiveness of the virtual and face-to-face environment in the learning process of Chemistry, specifically in the practical experimental component, for which 4 virtual laboratory practices were applied using the aforementioned software.

Table 3: Descriptive statistics of academic performance in a face-to-face manner

Component	n		Mediate	Sd	min	Max
CD	32	5,82	5,97	2,09	1,09	10
EAP	32	9,22	9,09	0,22	8,94	9,66

AAA	32	8,98	9,07	0,72	6,23	9,93
Notes 1st part	32	7,96	8,04	0,90	6,11	9,86

The grades corresponding to the first midterm obtained from the students in person, fifty percent of the students are above 8.04. This is in accordance with the fact that on average students are 7.96, deviating from that figure by an average of 0.90. There is a higher score in the learning component of teaching 10 and a lower score in the teaching component 1.09.

Table 4: Descriptive statistics of academic performance online

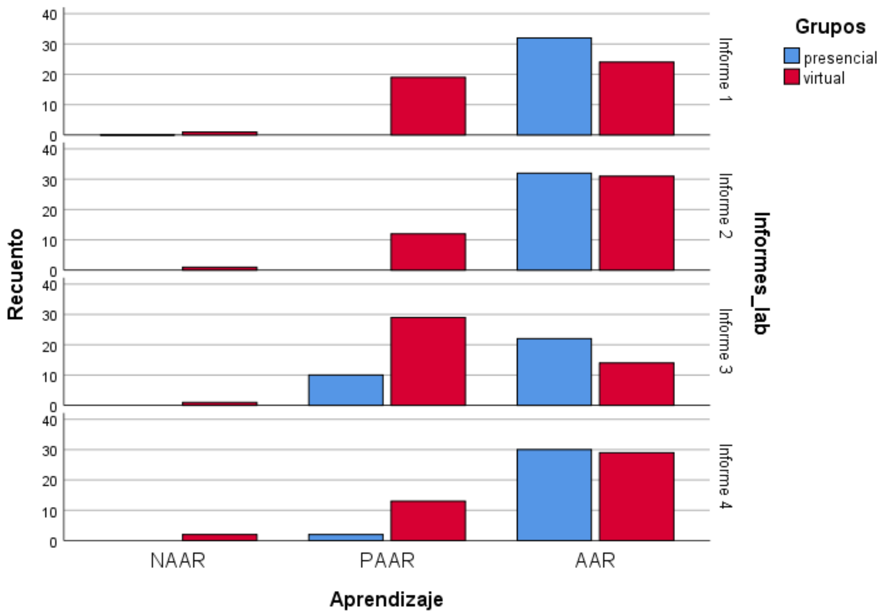
Component	n		Mediate	Sd	min	Max
CD	45	5,69	5,63	2,03	0,57	9,73
EAP	45	7,07	7,17	1,28	2,09	9,03
AAA	45	7,37	7,57	0,88	2,57	8,20
Notes 1st part	45	6.76	6,69	1,14	1,80	8,27

The grades corresponding to the first midterm obtained from the students virtually, fifty percent of the students are above 6.69. The above is in accordance with the fact that, on average, students are 6.76 deviated from that figure of 1.14. There is a higher score in the learning component of teaching (9.73) and a lower score in the teaching component (0.57).

Comparative analysis of practical-experiential learning in virtual and face-to-face ways

Figure 1 presents a comparison between the laboratories carried out by the students in person and virtually, showing a greater scope of the learning required in the face-to-face laboratory.

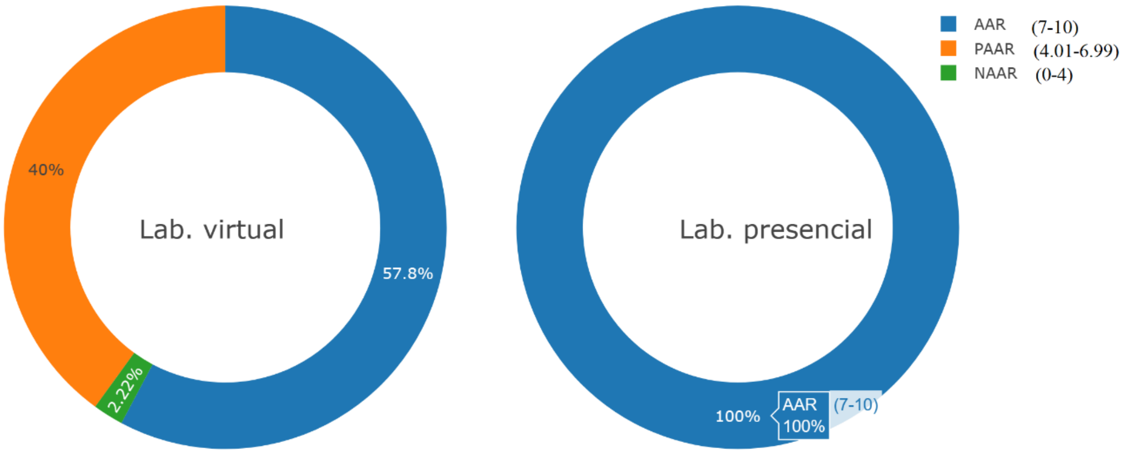
Figure 1: Comparison by laboratory reports



Source: Authors' own elaboration obtained from laboratory reports

Figure 2 shows the comparison between the academic performance of students in the experimental practical component, both face-to-face and virtual, there is a greater scope of the learning required in person with 100%.

Figure 2: Hands-on-experiential learning



Source: Authors' own elaboration obtained from the minutes corresponding to the first partial

To prove the hypothesis proposed, the normality test was performed, for this the Shapiro will test was used because normality is contrasted when the sample size is less than 50 observations (Flores, 2021), so that for both groups specifically in the practical experimental component in person and virtually, the value of bilateral asymptotic significance was obtained 0.001 lower than the level of significance (α=0.050), which corresponds to a non-normal distribution, i.e. the sample does not come from a normal population

As the data are not normally distributed, the Mann-Whitney U statistical test, also known as Wilcoxon's sum of ranges test, is a non-parametric statistical test used to compare two samples or groups. The characteristics that the data must have in order to be analyzed by this test are the following:

1) The dependent variable should be measured at the ordinal or continuous level

2) The independent variable should consist of two groups

3) There should be independence of each group's observations

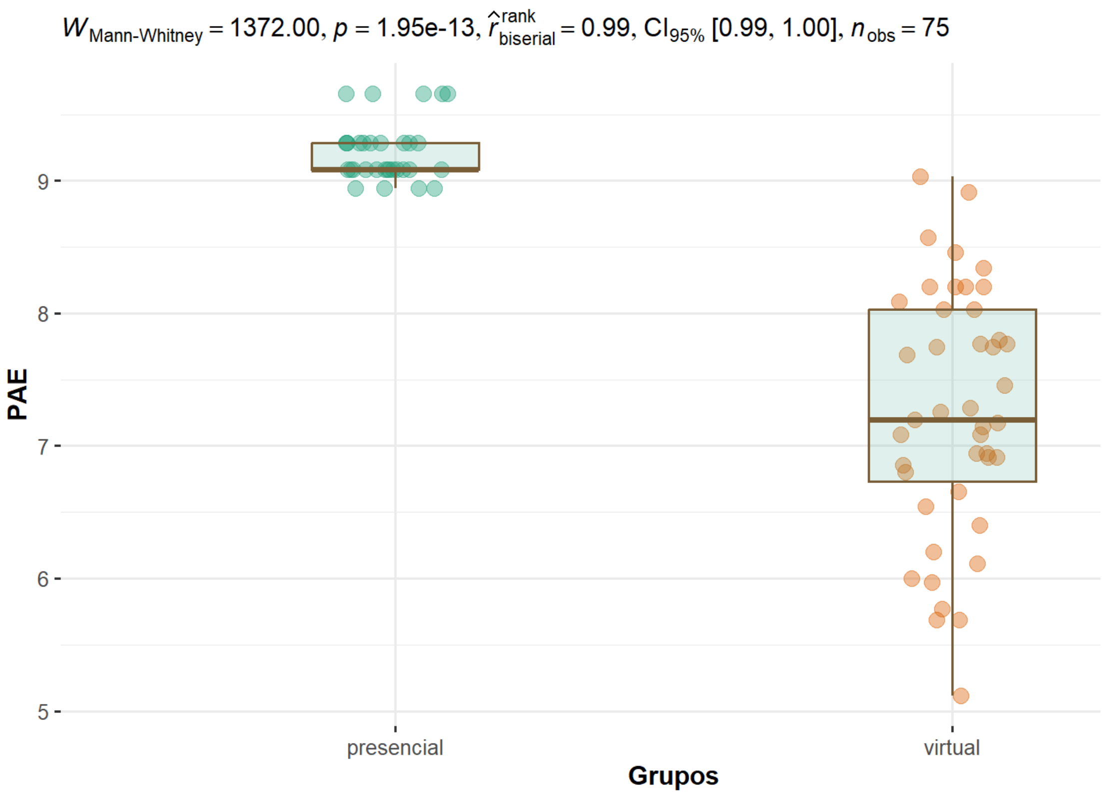
4) The two variables are not normally distributed

The following are the hypotheses to be demonstrated:

Null hypothesis: There is no difference in the scores of the experimental practical component between the students who carry out the activities in person and virtually.

Alternative hypothesis: There is a difference in the scores of the experimental practical component between students who carry out the activities in person and virtually.

Figure 3: Hypothesis Testing Practical Experimental Component



Source: Authors' own elaboration obtained from the minutes corresponding to the 1st partial

As can be seen, the Mann-Whitney U statistic was from 1732 and the p-value (Bilateral Asymptotic Significance) of , which is less than the significance level 0.05. This indicates rejecting the null hypothesis and concluding that there is a significant difference in the scores of the experimental practical component between students who carry out the activities in person and virtually. $1{,}95\text{x}10^{-13}$

Likewise, the descriptive statistics indicate that the median score of the experimental practical component for students who carry out the activities virtually (7.17) is lower than the median score of the activities in person (9.09). In addition, there is greater dispersion of the data in the virtual group than in the face-to-face group, this is demonstrated by the visualization of the colored dots shown in Figure 3.

On the other hand, the effect size of the Mann-Whitney U test is realized through the significance effect r (range-biserial correlation), in this case a value of 0.99 has been obtained as shown in Figure 2, which indicates that the size of the association is very large and significant between the ratings of both groups. this is corroborated according to the scale proposed by Funder, 2019 presented in Table 5.

Table 5: Test of Effectiveness

Value of r	Estimate
R<0.05	Tiny
0.05<=r<0.1	Very small
0.1<=r<0.2	Small
0.2<=r<0.3	Medium

0.3<=r<0.4	Large
r>=0.4	Very large

Source: Excerpted from Software R studio: Funder & Ozer (2019) ("funder2019", default)

The results show that the activities developed motivate the students to inquire about the contents covered in class, stimulate their participation in the development of the activities, but above all contribute to the interpretation of conceptual and procedural contents of the topics developed in the area of Chemistry, especially in the laboratory with their teacher and classmates.

From the constructivist conception of learning, and in contrast to mechanical or rote learning, it is assumed that meaningful learning is, in itself, motivating because the student enjoys performing the task or working on these new contents; They understand what has been done and give meaning and application to what they have learned, giving rise to an intrinsic motivation, emerging a variety of satisfactory positive emotions that favor learning but in a smaller proportion in relation to the physical environment of the laboratory.

Each activity leads to "promoting a more active, participative and individualized teaching, where the scientific method and the critical spirit are promoted, developing elementary skills and techniques in the students" (Chasi, M. 2017:11).

Research carried out in recent years has shown the impact on conceptual learning is the same with interactive simulations, it has been shown to have a positive impact on student learning and the development of scientific skills (López 2020:11).

On the other hand, some science education researchers recognize and counter the effectiveness of virtual learning in the sense that students do not always connect with the authenticity of virtual lab spaces (Hsu, et al., 2017; Wu et al., 2013). Payne (2005) also reported that 53% of students participating in a study on high school did not pass virtual learning at all. Other disadvantages of e-learning recorded included lack of technological knowledge, loss of realism, and more immersion in a virtual environment. (Penn, & Ramnarain, 2019: 90)

On the other hand, when considering simulator-based experiments, it is worth referring to the study by Zendler and Greiner, at the University of Education in Ludwigsburg, Germany, which compared experimental and computer simulation approaches for the same learning content. The results showed that simulation works similarly to the experimental method, despite operating at different cognitive levels. Simulation work is considered particularly important to promote self-directed learning (Zendler & Greiner, 2020: 10).

Virtual and remote labs can contribute to the development of important practical skills, although they arguably cannot replace the student's physical interaction with the team. (Glassey & Magalhães, 2020:77)

In response to the research question "Is there any significant difference in the academic performance of students using the virtual simulators and the physical laboratory?" it is shown that there is a difference in academic performance as well as a better development of cognitive and procedural skills.

CONCLUSIONS

The general purpose of this research was to determine if there is any significant difference in chemistry learning between the virtual and physical laboratory, the results obtained from the survey demonstrate the preference of students to carry out experimental activities in person. Similarly, in the section on 'graphic representation', there are statistically significant differences in the data visualization in favor of the group of students who carried out the practical and experimental activities in the face-to-face modality. Likewise, the effect size of the Mann-Whitney U test demonstrates the size of the association between the two groups, which is very large and significant.

The activities carried out in the laboratory have been shown to improve the conceptual and procedural learning of the students, thus promoting a better academic performance in the content tests of the General Chemistry subject, compared to the application of virtual laboratories

In the academic performance of the students of the career of Pedagogy in Biology and Chemistry on the use of the Phet and Crocodile Chemistry 605 simulations for the learning of General Chemistry based on two aspects: cognitive and procedural, it was evidenced that they totally agree that the work in the laboratory is better than what is done with the virtual simulators described above. they are useful both for a better understanding of chemical phenomena and a better understanding of chemistry, contributing to their academic training in post-pandemic times caused by COVID-19.

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