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Scientific recreations to favor the learning of the periodic table in high school students with incomplete schooling

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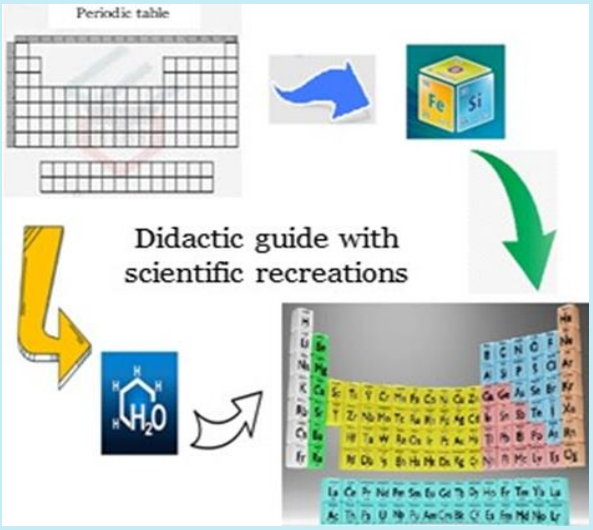
ABSTRACT: Didactic games for science teaching contribute to student learning and break with traditional teaching models. The objective of this study was to implement a didactic guide with scientific recreations to favor the learning of the periodic table in students with incomplete schooling in the 2022–2023 school year. For this purpose, an experimental, field and explanatory research was used. A population study was carried out with 60 students of the first year of high school of the "Velasco Ibarra" Fiscal Educational Unit. The main theoretical and empirical methods were used, as well as descriptive and inferential statistics for data processing, analysis and interpretation. A didactic guide with scientific recreations was elaborated to favor the learning of the periodic table in students with unfinished schooling, which was applied to the students of the "Velasco Ibarra" Fiscal Educational Unit, in the 2022–2023 school year. It was corroborated that the didactic guide with scientific recreations applied significantly improved the students' learning of the periodic table.



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1. Introduction

From the beginning, human beings have been interested in knowing the world around them, trying to explain each of the phenomena existing in nature, which led to what is known today as Chemistry, a branch of the natural sciences, which is present in all aspects of everyday life and, therefore, also in the educational field, although there are certain difficulties in this field, both in teaching and learning.

In this regard, Valdés (2019, p. 15) refers that: "Chemistry is one of the branches of science that brings together a large accumulation of abstract and complex information, which hinders the appreciation and understanding of topics in its teaching, causing deficiency in the development of scientific skills".

Chemistry as a science implies that students who learn by performing a scientific school activity not only recognize new ideas and identify evidence, but also learn to talk and write about it, to give a better meaning to those ideas and experiments (Sanmartí, 2008).

Tang and Rappa (2021) proposed a model intended to support students in the construction of scientific explanations in chemistry, which comprises three main components: (a) the premise: theoretical knowledge that provides the basis for the explanation, (b) the reasoning: logical sequences that follow from the premise, and (c) the result or conclusion: the phenomenon that is explained. According to these authors, since the genre of scientific explanation is not a familiar form of writing for many people, most students find it difficult to write the periodic table in a simple way, as they do not know where to start.

On the other hand, García Posso and Posso García (2017, p. 582) indicate that: "The lack of adequate teacher training has generated behaviorist practices that do not favor student learning, but favor dependence, lack of creativity and inability to think". It is worth mentioning that, under this perspective, Pérez (2018) suggests that, globally, in recent years, in terms of Chemistry teaching, links have been established between structure, properties and practical applications, which generates methodological variations in the teaching-learning process. This shows the need to look for novel methodologies that can really motivate students to learn in a meaningful way.

Therefore, Barahona and Constante (2019), mention that the methodology of the learning and teaching process in the baccalaureate is constituted by the objectives, knowledge, attitudes and values that students must learn, a different way of presenting the contents is sought, using innovative and at the same time everyday resources, with the purpose of achieving true knowledge in students.

The use of games is often considered in the literature as a test of interest when it comes to getting the student to actively participate in teaching and learning. Orlik (2002), in an extensive study on active methodologies in the teaching of science in general, and chemistry in particular, places this resource as one of the most important in this sense.

On the other hand, Yager (1991) points out that "taking part in focused games" places students in a scenario that facilitates their motivation and allows them to work on a wide range of skills. Similarly, didactic games, created individually or in groups, provide students with the opportunity to be creators of their own learning.

In this sense, Mondeja *et al.* (2001) specify a set of qualities and requirements that games meet and make them useful in the development of the teaching and learning process:

1. Games contribute to dynamize the students' activity in many forms of teaching organization, where, once motivated, they develop their cognitive activity;
2. They indirectly improve the efficiency of educational processes, since they demand greater reflective activity on the part of the teacher;
3. They must be used in a planned manner in correspondence with the educational intentions and their implications in the classroom.

Finally, games have two important points in the development of the teaching and learning process, namely: they are a learning tool and, at the same time, a learning strategy, since they mean a different way of working and learning.

According to Torres (2002), didactic games also interest and promote other qualities in students, such as self-control, honesty, security, care and concentration in work, meditation, the search for other ways to win, according to the rules of the game. to play, to initiate, to understand and connect with others.

The different types of games available for chemistry teaching should be explained in different ways. Orlik (2002), for example, distinguishes three major types of games applicable to the classroom, which he calls exercise games, occupational games, and knowledge quiz-type games.

Exercise games can be defined as easy-to-solve minigame problems, usually with pencil and paper, similar in structure to puzzles and word games. As a rule, these games are suitable for individual or small group work. Typical examples are word searches or crossword puzzles (Rannikmiae *et al.*, 1982). The reverse task is

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also feasible, i.e., the student himself is the one who designs new crossword puzzles with chemistry or science terms and concepts.

Occupational games consist of giving each student a *job*, which they must successfully defend and explain to their peers. For example, occupational games have been designed based on professions in the chemical industry around the production of organic compounds ammonia sulfuric acid, etc. A variant is the class-consultation, where only three roles are assigned to the students: teacher, assistant and inspector, who must answer questions posed by the rest of the class on a particular topic. This variant allows for better preparation of the group before an exam. A third option is to organize the occupational game in the form of a theater, which increases the motivation of the students.

The third and last type of games are quizzes that can be organized both in chemistry classes and in an extracurricular context (Franco-Mariscal *et al.*, 2012). In general, this type of game resembles a television program in many countries and may involve two or more teams of students. The game is preceded by a preparatory stage in which the teacher formulates a task to research both the chemical and general scientific literature on the topic. Depending on your level (high school or college) the questions should be of different difficulty.

Regarding the teaching of the Periodic Table, a traditional, theoretical and memoristic way has been generalized, which causes disinterest in students to learn and understand Chiriboga (2022). In this way, it can be said that, the activities of a teacher in the classroom can be difficult, since it requires planning, an organization with a favorable environment that allows teaching and learning according to the reality of each educational institution and therefore the students. Classroom management involves several factors to develop properly helping to improve student learning.

In Ecuador, there are many shortcomings in the educational context, not having found a global project that meets all the needs of the educational community. In view of this, Rengifo Ávila and Espinoza Freire (2019, p. 177) state:

> Ignorance of the importance of education for the development of the country leads to prioritize other sectors, mitigating the formation of citizenship. / The above brings us closer to a painful reality in which there are countless problems at the level of education in Ecuador, but it is complex to understand why they are not being solved, if they are key pieces of the country's development.

Another problem in Ecuador is student dropout, which is also caused by different factors: economic, labor, social and personal. In Ecuador, there are 5.7 million people who are in a situation of illiteracy or unfinished schooling, among which we have 692 316 people who require literacy, 979 743 people who require post-literacy, 3 132 586 people who require higher basic education and 927 468 who require Baccalaureate (Ministry of Education, 2019).

The Ministry of Education, as the institution in charge of guaranteeing the right to education, serves the population with incomplete schooling and educational backwardness through extraordinary educational services in three modalities: face-to-face, blended and distance.

In view of the above, the General Regulations to the Organic Law of Intercultural Education of Ecuador (Ministry of Education, 2015) in Article 151 states that:

> The evening session, which can only be offered to persons fifteen years of age or older, applies a blended learning modality through which a special curriculum is developed that determines 70% for face-to-face academic activities and 30% for academic activities of independent work under teacher supervision... (p. 46).

In another aspect, in evening education, when presenting students over the age of 18 with multiple daily responsibilities, it is difficult to capture their attention, so it is necessary to implement teaching methodologies different from the usual ones. In this regard, Rodríguez Lorbada (2017) states that there are different theories for adult learning, including: andragogy, transformational learning and experiential learning, and each of these theories converge in the same purpose: to develop learning techniques and experiences that are effective for adult learners.

It is imperative to change traditional methodologies for others that involve the students as the main actors in their own teaching-learning process, with the support of the teacher as mediator and strategist in the application of playful activities that reinforce learning (Galagovsky, 2007).

On the other hand, in the province of Manabí, specifically in the canton of Portoviejo, there are predominantly families of middle and low social strata that have educational lags, who, despite the inconveniences that have been presented to these people, decide to continue their studies and are called students with unfinished schooling, for which there are night educational institutions that ensure studies in an

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extraordinary way, adjusting the curricular content with the prioritization established by the Ministry of Education to serve this student population. One of these institutions is the "Velasco Ibarra" Fiscal Educational Unit.

Within the institutional reality of the "Velasco Ibarra" Fiscal Educational Unit, there are different problems, as follows:

- Few scientific-recreational activities in theoretical subjects;
- Insufficient learning skills in students;
- Scarce pedagogical resources for the correct teaching of the different subjects;
- Low student interest in classroom activities.

In this institution there are multiple insufficiencies in the teaching and learning of the periodic table. In virtue of the above, the objective of this research is to implement a didactic guide with scientific recreations to favor the learning of the periodic table in students with unfinished schooling in the first year of high school at the "Velasco Ibarra" Fiscal Educational Unit.

2. Methodology

The research was conducted using a mixed (qualitative-quantitative), explanatory approach and an experimental design. The main theoretical methods were used, namely: historical-logical, analysis-synthesis, inductive-deductive and hypothetical-deductive, to understand the object of study in its development, its history and logic, to discover the essential relationships and general characteristics among them, to determine generalizations and empirical laws, and to reach new conclusions and empirical predictions.

The following empirical methods and techniques were used to collect data on the indicators defined by each relevant variable: scientific, participant and covert observation, questionnaire, semi-standardized interview, measurement and the social experiment, due to the largely subjective nature of the object of study and the field of research, and the influence of multiple factors that are difficult to control.

For the processing, analysis and interpretation of the data collected, descriptive statistics were used, through the calculation of percentage values, measures of central tendency, measures of dispersion and construction of graphs. A population-based study was carried out, since 100% of the students of the First Year of the Unified General High School of the "Velasco Ibarra" Fiscal Educational Unit participated in the research, amounting to 60 students.

A quasi-experimental design was used, since a control group and an experimental group were configured. The research was developed in three stages: i) a pretest was made to the students of the two groups (control and experimental) to diagnose the knowledge and previous learning about the chemical elements of the periodic table; ii) the teaching and learning process was developed to the control group with the traditional method and to the experimental group the proposed strategy was applied with the resources and applications considered about the chemical elements of the periodic table and; iii) a post-test was applied to check the feasibility and relevance of the implemented strategy.

A didactic guide based on scientific recreations was elaborated to favor the learning of the periodic table in high school students with incomplete schooling, in a collaborative and team way, which consisted of six games, namely: Periodic table quiz, Chemistry App, Quimitris, Puzzle, Periodic table bingo and the atomic deck, all of them simple games, to experience a higher level of motivation and satisfaction with participative learning.

The research variables were: scientific recreations (independent variable) and learning the periodic table (dependent variable). Their operationalization appears in Table 1.

Table 1. Operationalization of relevant variables of the research.

Variable	Dimensions	Indicators	Techniques and instruments
Independent variable Playful activities	Attitudinal	Level of preparation on the use of technological resources in their learning	Survey
	Motivational	Students' level of motivation	Survey
	Aptitude	Acceptance of the ludic resources for their learning	Survey
Dependent variable Learning the periodic table	Academic performance	Percentage of students passed Average grade point average	Pretest Posttest

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The extraneous or extraneous variables identified were: i) teachers' motivation towards the changes, ii) students' motivation, iii) students' previous knowledge about the games and, iv) students' previous knowledge. The following actions were taken to control these variables:

- According to the motivation of teachers, work was done in two directions: a) teachers were motivated to use games for learning the periodic table, and b) teachers were prepared to motivate students about the importance and possibility of learning through games, for which workshops were held on the importance of this and the potential of playful activities to promote learning;
- The motivation of the students was controlled through practical activities, individually and in groups, about the relevance and usefulness of learning chemistry through playful activities, which included several examples of how to learn through didactic games. In this way, the students showed greater interest and paid more attention in the demonstrative classes conducted;
- With respect to the students' prior knowledge about the games, in the same practical activities executed to improve their motivation, several of them were demonstrated with some of the same games they would use during the teaching-learning process of the periodic table;
- Regarding the students' previous knowledge, an initial diagnosis was made and, based on the results of the same, several academic activities were carried out to level the students in those learning skills they should already have to start learning the contents taught in the subject of the periodic table.

3. Results and discussion

Based on the theoretical and methodological foundations and the contributions of the authors, this didactic guide with scientific recreations was elaborated to favor the learning of the periodic table in students with incomplete schooling in the first year of high school, as shown in Table 2.

Table 2. Didactic guide with scientific recreations to favor the learning of the periodic table in students.

Game	Description
Periodic table quiz	For teaching the elements of the periodic table in an interactive and simple way. It offers six types of game: guess the number of the element, its name or the group number to which they belong. All accompanied by a system of achievements and levels. It is free and compatible with Android devices.
Chemistry App	It has all the information about the elements of the periodic table. By touching any element, you can access its relevant data, allowing you to acquire knowledge and complete information in a simple way. It also contains additional tools to solve chemical reactions.
Quimitris	It is a game based on the classic Tetris for learning the elements of the periodic table in a fun way. The tiles, consisting of one, two, three or four chemical elements, fall from the top of the board and must be placed correctly on the periodic table. The game is divided into different levels that progressively increase in difficulty.
Puzzle	It consists of making a periodic table in three dimensions like a puzzle, where each square is a cube and, on each side, different characteristics of each element are represented: 1) name, 2) symbol, 3) atomic number, 4) photograph of the element, 5) representation of food, materials and medicines in whose composition the element is found, 6) group and period.
Periodic table bingo	Called Quica, it is a game of chance that consists of putting into a bag or drum, a certain number of chips, which contain the atomic number and symbol of a specific chemical element. The game is individual, so each student will have a cardboard, which has the symbol and atomic number of a chemical element at random.
The atomic deck	The atomic deck is a set of cards, arranged by color, with information about a chemical element, such as: symbol, atomic number, period, group, oxidation states, uses and applications. Students will have three cards and must form a word with the symbol of the chemical elements present on them.

The results of the survey applied to the students on the use of didactic tools using technologies and the realization of ludic activities to favor learning, corroborated that most of the Chemistry teachers do not use auditory didactic resources in their classes to reinforce the content on the chemical elements of the periodic table, knowing that these resources help to improve student learning, since of the total number of respondents, 53% affirm that the teachers do not use auditory didactic resources in the class and another 35% refer that they almost never or sometimes use them. Only 12% stated that they almost always use these resources (Table 3).

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Table 3. Absolute (A.F.) and relative frequency (R.F.) of responses to survey questions.

No	Questions	Always		Almost always		Almost always Sometimes		Almost never		Never	
		A.F.	R.F.	A.F.	R.F.	A.F.	R.F.	A.F.	R.F.	A.F.	R.F.
1	How often are auditory materials such as CDs and recordings used in Chemistry class?	0	0	7	12%	16	27%	5	8%	32	53%
2	Are slides, images, graphic organizers, etc., projected for the explanation of the elements of the periodic table?	10	17%	7	11%	10	17%	9	15%	24	40%
3	In chemistry class, do you practice the chemical elements of the periodic table using three-dimensional materials such as puzzles or 3D cubes?	1	2%	10	17%	14	23%	9	15%	26	43%
4	Do you find it useful to learn about the chemical elements of the periodic table through games?	19	32%	12	20%	17	28%	9	15%	3	5%
5	Are the lectures given by your chemistry teacher understandable at any time?	4	7%	5	8%	29	48%	21	35%	1	2%

In this sense, Blandín and Solórzano (2018) emphasize the incorporation of innovative strategies in the teaching-learning process of the chemical elements of the periodic table, because for the students this subject is very memoristic, with little understandable data, so it causes fear of the unknown, because of the little or little transmission of what was learned with the everyday, especially because of its complexity, which lies in that concepts with non-visual characters such as the atom must be explained.

Fifty-five percent of the respondents never and almost never the teachers project slides, images, graphic organizers and others, for the explanation of the elements of the periodic table; and only 28% of the students refer that they always or almost always do it. This corroborates that most teachers do not use, or do it very little, information technologies in the teaching-learning process of this subject, probably because this subject is usually complicated by the amount of information it has and the relationship that exists between it (Barazarte and Jerez, 2020).

Fifty-eight percent of the students stated that their teachers have never or almost never implemented three-dimensional materials such as puzzles or 3D cubes in their classes on the periodic table, while only 19% always or almost always do so, despite the fact that 52% of the students stated that they always or almost always find it useful to learn through games and that only 15% of the students stated that they understand the teacher. This shows that most teachers do not use, or do it very little, playful activities (games) to teach the theory and practice of the periodic table, despite the potential that these have to promote meaningful learning of students, in contrast to what was stated by Barazarte and Jerez (2020), who point out that teachers should use more creativity in this subject with entertaining and challenging activities for students, in order to facilitate their learning.

Some measures of central tendency and dispersion of the results of the pretest and posttest student scores, after applying the proposal to the experimental group and developing the process in the traditional way with the control group, are shown in Table 4.

Table 4. Descriptive statistics of the results of the pretest and posttest to the students.

Groups	Evaluation	Range	Minimum	Maximum	Median	Mean	σ
Control group	Pretest	6.00	1.00	7.00	4.00	4.00	1.4881
	Posttest	5.00	2.00	7.00	5.00	4.83	1.1805
Experimental group	Pretest	5.00	1.00	6.00	4.00	3.87	1.2313
	Posttest	4.00	5.00	9.00	8.00	8.10	0.9076

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In the control group, both in the pretest and posttest, as well as in the pretest of the experimental group, the great majority of the grades obtained by the students were at the low level (< 7.00 points). However, once the didactic strategy was applied, of the experimental group, 80.6% of the student's achieved grades of the high level (≥ 8.00 points); therefore, only six students of the group obtained grades of the medium level in the posttest.

In the pretest, in both groups, similar mean values were obtained. The analysis of the averages obtained by the students in the grades of both groups in the pretest, corroborate that they had a similar preparation in terms of previous knowledge, with which they started the teaching-learning process of the studied subject, so this previous learning did not influence the final results. This statement was confirmed by means of the Student's t-test for related samples, which reported a p value = 0.842 ($p > 0.05$); therefore, it can be affirmed with 95% confidence that there are no statistically significant differences between the means obtained by the students in the pretest in the control and experimental groups.

On the other hand, from the analysis of the means obtained by the students in the grades of both groups in the posttest, it was found that when applying a Student's t-test for related samples, a value of $p < 0.05$ was obtained; so it can be affirmed with 95% confidence that there are statistically significant differences between the means obtained by the students in the posttest in the control and experimental groups, which corroborates that the recreations applied did improve the academic performance of the students in terms of the periodic table. This agrees with Arce Urbina (2022), who points out that experimentation has great value in the teaching of natural sciences, since it is essential for students to assimilate a subject, exposing them to different and novel experiences so that they achieve greater motivation in their learning.

Likewise, from the analysis of the means obtained by the students in the pretest and posttest grades of the control group, it was found that when applying a Student's t-test for related samples, a value of $p = 0.268$ ($p > 0.05$) was obtained; so that it can be affirmed with 95% confidence that there are no statistically significant differences between the means obtained by the students in the pretest and posttest in the control group, which corroborates that the students of the control group did not significantly improve their academic performance in learning the periodic table.

This result corroborates Cuichán (2018), who refers that, in order to improve student learning in the subject of Chemistry, it is necessary that teachers plan their classes with strategies that allow students to assimilate it, in a more attractive, interesting and participatory way during the teaching-learning process, in order to achieve meaningful learning. In this sense, Orlik (2002) refers those teachers should incorporate into the curriculum, didactic and playful strategies that allow students to acquire knowledge and skills that are more attractive, interesting and participatory during the teaching-learning process, in order to achieve meaningful learning.

4. Conclusions

The elaboration of a didactic guide with scientific recreations to favor the learning of the periodic table in students is an effective tool, since it is based on simple games that help students to better understand the concepts on this topic and apply them in practical situations, experience a higher level of motivation and satisfaction with learning, work collaboratively and as a team, to benefit their participation and exchange of knowledge among them.

The implementation of the didactic guide with scientific recreations to favor the learning of the periodic table in high school students with incomplete schooling, improved the academic performance and the motivation and attitude of the students towards their learning, as well as their perception and satisfaction with respect to the usefulness of the games to favor learning.

Authors' contribution

Conceptualization: Castro Valdiviezo, H.; Batista Zaldívar, M. A.
Data curation: Castro Valdiviezo, H.; Batista Zaldívar, M. A.
Formal Analysis: Castro Valdiviezo, H.; Batista Zaldívar, M. A.
Funding acquisition: Not applicable.
Investigation: Castro Valdiviezo, H.; Batista Zaldívar, M. A.
Methodology: Castro Valdiviezo, H.; Batista Zaldívar, M. A.
Project administration: Castro Valdiviezo, H.
Resources: Castro Valdiviezo, H.
Software: Batista Zaldívar, M. A.
Supervision: Batista Zaldívar, M. A.
Validation: Castro Valdiviezo, H.; Batista Zaldívar, M. A.
Visualization: Castro Valdiviezo, H.; Batista Zaldívar, M. A.
Writing – original draft: Castro Valdiviezo, H.
Writing – review & editing: Batista Zaldívar, M. A.

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Data availability statement

The data will be available upon request.

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