Playful strategy applied to teaching and learning analytical chemistry

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ABSTRACT

Mediated learning is a teaching model in which a mediator stands between the learner and the world of stimuli, facilitating interpretation and understanding. This model has numerous modes of application, one of which is playful activity, or didactic games. This work presents the proposal to develop a didactic game, entitled "Analytical Chemistry Target Shooting", as an auxiliary tool in the teaching and learning process of analytical chemistry in higher education courses, especially for introductory subjects. For its construction, low-cost and easily accessible materials were used, aiming for a better applicability of the method, with the game consisting of a pair of darts, a target, a set of question cards of three levels of difficulty, a board and markers of the players. Therefore, a board game was obtained that leads to the fixation of the content taught in the classroom, in a relaxed and cheerful way, contributing to making chemistry teaching less complicated, tedious and aversive to the student, who becomes a more active in their learning.

Keywords: Active methodologies, Higher education, Teaching instruments.

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INTRODUCTION

Mediated learning is seen as a form of interaction that develops basic attitudes and skills for effective learning, enabling a dynamic of deconstruction and reconstruction of knowledge and information, with a mediator interposing between the learner and the world of stimuli, facilitating interpretation, and understanding (Feurstein, 1997; Demo, 2004).

One of the possible mediators of the teaching-learning process would be playful activity, appearing as an alternative method that helps this process. In this sense, it appears that playfulness contemplates the criteria for effective learning, in the sense that it draws attention to a certain subject, in which its meaning can be discussed among all participants and the knowledge generated from the playfulness activity can be transported to the field of reality (Coscrato, 2010).

From a playful perspective, it is not enough to manufacture what is already regulated; imaginative and rational strength becomes essential for articulating content that opens up to understanding, allowing critical thinking (Gadamer, 1985).

Playfulness should be considered as a methodological form that facilitates the construction of concepts, the reinforcement of content, sociability between students, creativity and the spirit of competition and cooperation, to the point of making this process transparent, ensuring mastery over the objectives proposed (Fialho, 2011).

Playful practices are capable of awakening students' attention, as well as their motivation and engagement in the activities carried out in the classroom, and, in this way, the anchoring of new knowledge ends up being more significant (Hoppe; Kroeff, 2014).

The discipline of Analytical Chemistry, which comprises the branch of chemistry that deals with the identification and determination of the composition of the constituents of a given sample, being an experimental science by nature (Vasconcelos, 2019), despite being evidently important, can be considered little attractive to students in related areas, especially when the content is taught only with emphasis on theory and presentation of decontextualized experiments (Pereira, 2011).

With the intention of combining play with education in the training of health professionals, it was proposed to develop a didactic game for teaching Analytical Chemistry, more specifically on the topics: gravimetry; chemical balance; volumes of neutralization, precipitation, complexation, oxidation-reduction and potentiometry, this game being constructed with low-cost materials and easy to perform in the classroom, in an introductory course in this area of chemistry.

THEORETICAL FRAMEWORK

PLAY IN TEACHING

Ludic has its origin in the Latin word 'ludus' which means 'game'. If thought only according to its origin, the term playful would only be referring to playing, playing, spontaneous movement.

However, play began to be recognized as an essential trait of the psychophysiology of human behavior, so that its definition was no longer a simple synonym for play, as the implications of the need for play went beyond the demarcations of spontaneous play (Almeida, 2009) . In this sense, playfulness encompasses games and games, but it is above all a human need, that is, it is part of human development (Marques, 2012).

Play is an activity with intrinsic educational value, but in addition, this method has been used as a pedagogical resource. Thus, there are several reasons that lead educators to use playful activities in the teaching process. As a teaching tool, it makes it possible to create a pleasant environment for students to develop in a meaningful way. Thus, the search for creativity to improve the student's cognitive skills becomes pleasurable. Furthermore, it has the ability to sharpen the senses (Macedo, 1995).

The concept of game, within the educational context, refers to situations given between two or more individuals and that occur within a specific set of rules, being systems in which players (students, and sometimes the teacher as well) develop a conflict guided by deliberate rules that will lead to a quantifiable result (Salen; Zimmerman, 2012).

Regarding the issue of game rules, Huizinga (1993, p. 33) states that:

> "A voluntary activity carried out within certain and determined limits of time and space, according to freely agreed but absolutely obligatory rules, with an end in itself, accompanied by a feeling of tension and joy and an awareness of being different from life everyday."

The use of playfulness in education is greater than the use of simple games to pass the time, being a form of action inherent to human beings, which does not depend on their age.

There are two definitions that deserve to be highlighted, which are presented by Cunha (2012, p.95):

> " [...] about games in teaching it is important to differentiate and define two terms: educational game and didactic game. The first involves active and dynamic actions, allowing broad actions guided by the teacher, which can occur in different locations. The second is one that is directly related to the teaching of concepts and/or programmed activities and that maintains a balance between the playful function and the educational function of the game, and is generally carried out in the classroom or laboratory. [...] a didactic game in terms of general aspects is educational, as it involves playful, cognitive, social actions, etc., but a game that is educational cannot always be considered didactic. This, however, does not minimize or reduce the importance of both."

It is worth noting that four important precautions must be taken into account when using playful activities in the classroom, the first of which is prior testing of the teaching resource with the intention of avoiding unpleasant surprises when implementing it in class. . The second precaution to take is to carry out a brief summary of the content to be worked on through the playful activity, as this content must have already been worked on and must be reviewed before applying the activity, to

make better use of the resource used. Thirdly, the need to check the rules with students stands out, so that they can clearly understand the activity. And finally, the fourth precaution would be the development of subsequent pedagogical activities related to the activity to investigate the value of the playful activity as a teaching tool, that is, evaluation of the activity developed (Lozza; Rinaldi, 2017).

Playfulness and Chemistry Teaching

Teaching practice in chemistry teaching continues to be predominantly traditional, which makes the discipline abstract, monotonous and with an extremely fragmented view of knowledge, in addition to being considered “difficult”, as it is a science with several formulas, calculations, names and symbols.

In agreement with this idea, Fialho (2007) highlights that students' lack of interest is often due to the teacher's imposing way of passing on content in a cold and distant way, making it necessary to arouse interest in what is taught through more attractive language, trying everything possible to bring the content closer to the maximum experience of each person's reality. Totally decontextualized chemistry propagates itself as an abstract science incapable of being present on a daily basis, thus it can only become a difficult, exhausting discipline that is impossible to relate to everyday life. In this way, the importance of teaching how chemistry is present in each person’s daily life can be seen. Silva, Mettrau and Barreto (2007) also add that there is a need for students to understand scientific statements and the construction of science itself.

Cunha (2012) highlights that the function of the game in chemistry classes should not be memorization, but, if it is related to names and symbols, the intention should be to familiarize students with scientific language, contributing to “work” (reduce) students’ difficulty with scientific language.

Fortunately, the application of recreational resources has already been the subject of several studies, mainly in basic education, and Table 1 presents some of these studies found in the literature.

Table 1. Examples of works with playful proposals in teaching chemistry

Author(s)	Proposal
Soares, Okumura and Cavalheiro (2003)	Teaching chemical equilibrium.
Farias (2004)	Concepts of density, thermal expansion and energy transformation through the use of a "Lava-Luz" type luminaire.
Oliveira and Soares (2005)	Jury to discuss concepts related to the environment.
Soares and Cavalheiro (2006)	Board game to cover thermochemistry concepts.
Franco-Mariscal and Cano-Iglesias (2008)	Learning the chemical elements of the Periodic Table, relating the map of Brazil and the names of the states of Brazil.*
Santos and Michel (2009)	Game with the theme of acidity of organic and inorganic compounds.
Filho et al. (2009)	Playful activity (crosswords) about concepts, definitions and episodes of Atomic Theory.
Godoi, Oliveira and Cognoto (2010)	Card game about Periodic Table
Dos Santos et al. (2024)	Roulette for teaching chemical elements in undergraduate pharmacy classes (higher level).

* Interdisciplinary proposal, as it relates Chemistry and Geography.

Soares (2004) admits that the use of playful activities in chemistry teaching is recent both nationally and internationally and presents several examples of this type of playful activities, such as the use of stamps and prints; a kind of real estate bank where chemical substances are bought and sold; mystery stories involving chemical concepts in adventures by the duo Sherlock Holmes and Watson; comic books, among many others.

PLAY IN HIGHER EDUCATION

Teaching aimed at the adult population, especially in higher education, has a variety of challenges, which, in order to be overcome, require the use of diverse strategies, one of which is the use of recreational activities, which are generally extremely positive. , after overcoming initial barriers (Hoppe; Kroeff, 2014). However, learning based on playful activities is still widely thought of as something exclusive to early childhood education, but they can be present from early childhood education to postgraduate studies, since any teaching and learning process can be permeated by moments of joy, well-being and pleasure (Grossi, 2017).

In Brazil, higher education or university education, after reforms that took place in the 1990s, has been seeking new methodological ways of teaching, but always based on the fact that this level of education aims to "train professionals who develop, stimulate and expand the areas of science, technology and culture" (Silva , 2014, p. 415), in addition to which it must also be considered that "in Higher Education, the student – as well as in other levels of formal education – is a subject training. The individual development of these subjects therefore passes through collective social activity" (Quadros ; Mortimer, 2014, p. 260).

A didactic game presents a concrete collaborative potential in terms of developing students' skills, abilities, knowledge, attitudes and abilities (Hoppe; Kroeff, 2014), and, in this sense, Batllori

(2009) provides a list of items, presented in Table 2, which are likely to be achieved through a playful activity developed even in Higher Education.

Table 2. Possible benefits of recreational activities

Possible benefits:
Promote mobility
Stimulate communication
Help develop imagination
Facilitate the acquisition of new knowledge
Encourage individual and group fun
Facilitate the observation of new procedures
Develop logic and common sense
Provide experiences
Help explore potential and limitations
Encourage acceptance of hierarchies and teamwork
Encourage trust and communication
Develop manual skills
Establish and review values
Streamline Cunning and Talent
Help in addressing transversal themes and content
Speed up verbal, numerical, visual and abstract reasoning
Encourage respect for other people and cultures
Learn to solve problems or difficulties and look for alternatives
Encourage acceptance of standards

Source: Batllori (2009, p.15), adapted.

When developing a playful methodology, the game itself is not its purpose, but it is the integrative axis between didactic content and the acquisition of information, which is effective through pedagogical actions of a playful nature (Grossi, 2017), and , so “cognitive skills are easily sharpened, which allows learning to be conducted fluidly, in addition to helping the teacher-student relationship.” (Marriel et al., 2021, p.3).

MATERIALS AND METHODS

The game presented in this work concerns a teaching tool that assists in the teaching and learning process of analytical chemistry, having been proposed to be applied in an introductory course present in the training of bachelors in pharmacy, but can also be applied in other higher education courses. It was entirely designed by a group of students from the Pharmaceutical Chemical Analysis discipline, which is the introductory discipline to the study of analytical chemistry at the Federal University of Pará, located in the North of Brazil, in the middle of the Amazon.

The elaborate game was called **Analytical Chemistry Target Shooting** , as it is a game containing questions and answers about analytical chemistry, using a conventional board and a target shot that defines the number of squares (parts of the path on the board) to advance and the degree of difficulty of the questions that the participant will answer regarding analytical chemistry.

The game basically features four constructive elements: target shooting; a pair of darts; a board; game pins (three and different colors) and a set of cards consisting of 30 cards, composing 3 groups of 10 cards.

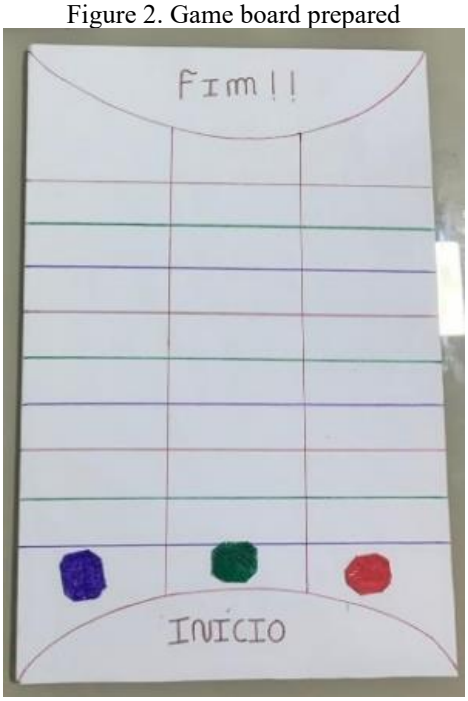
The target shot and the pair of darts, shown in Figure 1, were purchased ready-to-use at a stationery store. The target shot is made up of a circle of yellow, red, green and purple colors (with written numbers: 10; 20; 30 and 40) and a pair of darts that stick to the circle (target) using magnets. This material is low cost and easy to access.

Figure 1. Target shooting and game darts

Alternatively, the target shooting could be made with a sheet of cardboard paper on which circles would be drawn and painted according to the color code shown in Figure 1 (yellow, red, green and purple), and this circle would then be glued onto the sheet. of Styrofoam, with subsequent cutting of this sheet. The donor pair could be made with a soft drink straw, with a small nail or pin inserted into one of the ends. The ready-made material was chosen as it is safer and more durable.

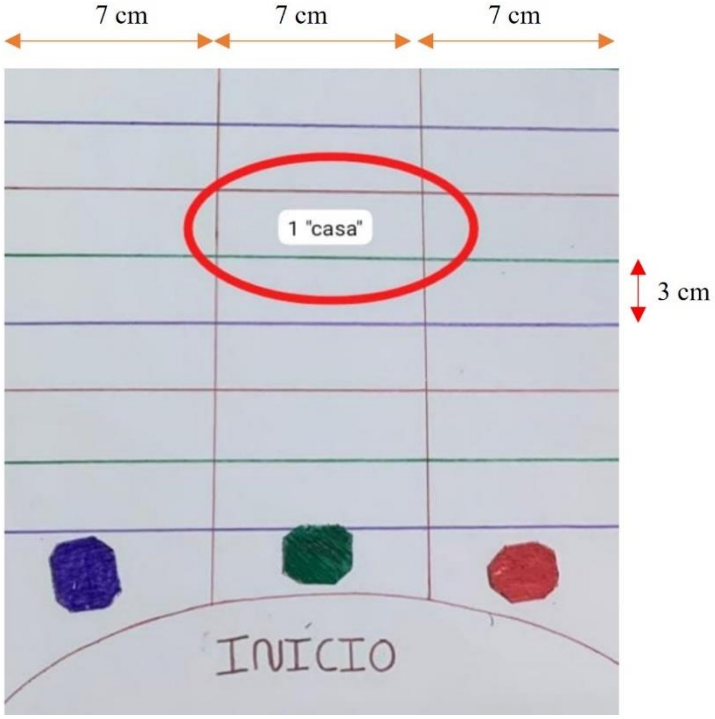
The game board, shown in Figure 2, was made by the team of students, using the following materials: white cardboard; paper scissors; silicone glue; colored pens (red, green, purple and brown); ruler; pencil; rubber; stylus and MDF (*Medium Density Fiberboard)* surface , with dimensions of 21 cm by 40 cm, for the base of the board, but which can be replaced by a common sheet of Styrofoam, of any thickness.

Figure 2. Game board prepared



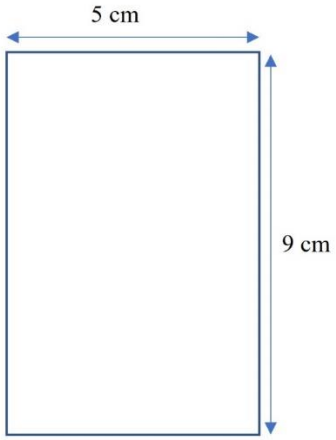
Using colored pens, straight lines were traced on the sheet of white cardboard, starting from a semicircle, where the word “beginning” was written, and arriving at another semicircle, where “End” was written. Then straight lines were drawn perpendicular to the first ones, thus forming rectangles (board houses), with dimensions of approximately 7 cm by 3 cm, with the entire arrangement measuring 21 cm by 40 cm (Figure 3). Then the outline was cut and glued onto the MDF surface with silicone glue, to give it greater stability.

Figure 3. Highlight of a “house” on the board



To construct the set of cards containing the game's questions, the following materials were used: white cardboard in the colors white, red, purple and green; scissors; paper glue; printer and common graphite paper, A4, as well as a computer with the World program for typing the questions. The dimensions of each game card were 5 cm by 9 cm (Figure 4).

Figure 4. Sizing of game cards



The construction of the game cards followed the following steps:

1- Thirty rectangles, with the dimensions of Figure 3, were cut from sheets of white cardboard, using scissors, and ten green rectangles, ten red rectangles and ten purple rectangles, were also cut, in the same dimensions, from using cardboards of the respective colors. Alternatively, in the absence of colored cardboard, white cardboard painted with colored pens could be used.

2- Each white rectangle obtained was glued, with paper glue, to one of its sides with a colored rectangle (either purple, red or green). Forming, then, three groups of cards, each with ten components and a discriminating color. These colors indicate the degree of difficulty attributed to the question on the card, with: purple associated with the easy level; green to medium and red to difficult.

4- The thirty questions prepared (Tables 3, 4 and 5) were typed into world, printed, remembered and pasted on the cards according to the level of difficulty of the questions (green, purple and red). The degree of difficulty of the questions was freely established by the teachers who developed the didactic game. The answers were printed in three lists for the game leader to monitor.

Table 3. Easy level questions (purple cards) prepared for the game

Question	Response
1- Chemical analysis is classified into 2 types, what are they?	Qualitative and quantitative analysis.
2- What do the qualitative and quantitative methods of chemical analysis consist of?	Qualitative: Identify the types of elements, ions and molecules that make up the sample. Quantitative: Determine the amount of each of these components.
3- How to calculate the pH of an acidic solution? Formula)	$pH = - \log [H^+]$
4- Which indicator is used in argentometry?	Silver nitrate.
5- What relationship should exist between the volume of the end point visually indicated by the indicator and the volume of the theoretical equivalence point?	The closer the better, as it reduces titration error.
6- Define buffer solution.	Mixture of a weak acid and its conjugate base or a weak base and its conjugate acid, which resists changes in pH.
7- Neutralization volume is classified into two classes, what are they?	Alkalimetry and acidimetry.
8- If the titrant agent is NaOH and the titrant is HCl, how is this neutralization volumetrics classified?	Alkalimetry.
9-What is the indicator used in iodometry?	Starch.
10-When determining the hydrogen peroxide content using previously standardized potassium permanganate, which indicator should be used?	Potassium permanganate.

Table 4. Medium level questions (green cards) prepared for the game

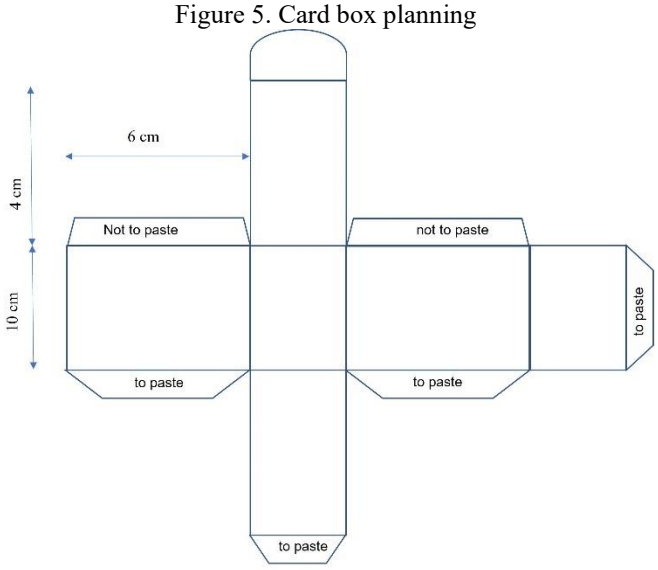
Question	Response
1- In a complexation reaction, how is the end point determined?	Instrumental and visual methods using metal indicators.
2- What causes changes in a chemical balance?	Changes in: temperature, concentration and pressure.
3- What are the two main desirable characteristics in a primary standard?	High purity, stability.
4- At what moments in a titration are calculations necessary to generate a titration curve?	Before the start of the degree, before the equivalence point, at the equivalence point and after the equivalence point.
5- What is the role of EDTA in complexation volumetrics?	It is used as a titrant to determine the concentration of metal ions in the sample.
6- In redox volumetry, what oxidizing agents are used in the iodimetric, iodometric and iodatometric methods, respectively?	Iodine, iodine and iodate, iodate.
7- How can gravimetric analysis be classified?	Precipitation Gravimetry; volatilization and electrogravimetry gravimetry.
8- What is the name of the CN^- and S^{2-} ligands?	Ciano and uncle.
9- Define complex compound.	It is the compound resulting from the combination of a metallic ion or any substance with a group donating a pair of electrons.
10- What is the dp or potential of the solution before adding the titrant?	It cannot be calculated, as the concentration of the titrate is unknown.

Table 5. Difficult level questions (red cards) prepared for the game

Question	Response
1- What does Chatelier's Law consist of?	If a system at equilibrium is disturbed, the equilibrium position will shift in such a way as to attenuate the disturbance.
2- In relation to quantitative analytical methods, mention the classical and instrumental methods.	Classics: gravimetric and volumetric methods. Instrumental: electroanalytical, spectroscopic and separation methods
3- Differentiate between accuracy and precision	Accuracy: is the degree of agreement between the found value and the true value. Precision: is the degree of agreement between repeated measurements of a quantity. It expresses the "reproducibility" of a series of measurements.
4- When and for the Q test is it used?	It is only used when the number of results is less than 10, it is used to reject coarse values in a series of measurements.
5- In redox volumetry, Daniel's cell has cathode and anode electrodes. What reactions do they suffer?	Reduction and oxidation.
6- In the redox reaction: $Zn(s) + Cu^{2+}_{(aq)} \rightarrow Zn^{2+}_{(aq)} + Cu(s)$, which is the reducing agent and which is the oxidizing agent?	In this reaction, the Cu^{2+} ion is acting as an oxidizing agent, as it accepts electrons during reduction, and zinc (Zn) is acting as a reducing agent, as it loses electrons during oxidation.
7- What is the potentiometric method and when is it used?	Methods that are based on measuring the potential difference of an electrochemical cell in the absence of current. It is used when the analytes are dark.
$_3$ solutions ?	NaCl
9- What are the two most used argentometric methods?	Mohr's method and Volhard's method.
10- Why can't sodium hydroxide be considered a primary standard?	Due to its hygroscopicity, that is, its ability to absorb moisture from the environment.

To store the game cards produced, a box measuring 6 cm by 10 cm by 4 cm was made with white cardboard, ruler and pencil, as well as paper glue, according to the sizing given in Figure 5.

Figure 5. Card box planning



To identify each player in the game, small pieces were cut out with the same material as the cards and different colors to differentiate each player. These pieces were colored with purple, red and green pens.

Figure 6 shows a photograph of all the game pieces already produced.

Figure 6. Game pieces ready

GAME RULES

The elaborate game can be played by a minimum of two players (or two teams of players) and a maximum of three players (or teams of players), requiring a match organizer/judge, who can be the subject teacher, a monitor, or even one of the students in the class, previously elected for this role within the game, in addition to a game kit (a board, a shooting target, sets of question cards, player identification pieces and sheets with the answers to the questions).

The order of the players is defined by a simple draw, using a common die, or another random draw method, or by simple agreement between the participants, and the target (Figure 3) can also be used to define the order of the participants' moves. , with the first to play being the one who reaches the highest target score and the last one the lowest.

The game's target shooting (Figures 1 and 6) is made up of a circle divided into sections containing numbers and colors, each color indicating the degree of difficulty of the questions and their respective scores. To play, the player (or team) must try to hit the target correctly, that is, in the center of the section that contains the numerical value. The dart cannot reach the center of the target which has no numerical value (situation exemplified in Figure 1), it must also not fall and cannot stay on top of the line, if this happens the player (or team) loses the move and the next one continues.

In Figure 7, for example, the region of the target where if the player (or team) shoots is marked with a circle, he will compete for 40 points.

Figure 7. On-target indication of a 40-point region

The player (or team) that hits the target correctly must answer a question to advance. The question will be drawn from one of three sets of cards, according to the color of the region where the dart hit the target, for example, in the case of Figure 7, the player (or team) must answer a difficult question (red color).

The player (or team) who gets an easy question (purple) correct wins 10 points and advances 1 space; The player (or team) who gets a medium question (green) correct wins 20 points and advances 2 spaces; The player (or team) that answers a difficult question correctly (red) wins 40 points and advances 4 spaces (as illustrated in Figure 7). On the target there is also a yellow section that indicates the loss of 30 points and the regression of 3 spaces, if the player (or team) targets in that section.

Each player (or team) has one chance to correctly answer the drawn question. In case of an error in the answer, the participant does not advance and their card/question is returned to the game, and can be answered later by the player himself or by another.

The game judge is in charge of checking whether the participants' answers are correct, according to the answer sheets. However, it is up to this component of the game to judge possible answers that differ from those contained in the lists, since the intention is not to take a single textual construction as certain, in the case of which there may be changes in the way of responding (not in content, of course).

If any color of questions runs out, the player (or team) will continue with the remaining questions, and if they reach the target session in which the color ran out, they will have a new chance to play.

The player (or team) who first completes the 10-square route to the finish line on the game board wins. If all question cards are exhausted, the player (or team) closest to the finish wins.

GAME TESTING

After having its parts and rules developed by the team of students, the game was tested with all students in the class of the subject to which the team's students belonged to evaluate it, realizing the applicability of its rules and collecting possible modifications favorable to the game. good progress of the game and acquisition of knowledge.

DISCUSSION

The main result of this work is the creation of an educational tool aimed at learning analytical chemistry, to possibly be used in introductory discipline classes in this branch of Chemistry, as is the case of the discipline in which this resource was developed.

In its construction, simple, easily acquired and cheap materials were used, and it is also possible to build with other even cheaper and simpler materials, as previously presented.

This feat consists of a board game made up of several pieces that help to fix the content taught in the classroom. Therefore, the game named Analytical Chemistry Target Shooting helps in the teaching and learning process in a more relaxed and inviting way, serving as a fun way to exercise previously worked concepts and definitions.

Studies show that most students have difficulty learning chemistry and consider it to be an extremely boring subject with lots of formulas, calculations, nomenclatures, etc. However, when the subject is not taught using traditional methods, the chances of the student being interested in the content are much greater, an example of this is the use of playful activities (Lima et al., 2011). In this context, the use of educational technologies such as the one described in this work makes chemistry learning more effective and interesting since activities that are normally associated with leisure can also be associated with the classroom and studies.

Didactic games can give students a slight competition to determine the winner, this fact boosts interest in the game and consequently learning, since to win they will have to make an effort to remember and learn the knowledge taught in the classroom. These tools are useful for both students and teachers who can also relax while playing (Dos Santos, 2018).

Another applicability for the highlighted tool is the assessment of students' learning of the subject. Since, studies show that traditional assessment through tests does not correspond to the student's real learning. Therefore, new methods of assessing learning have been sought and one of them is through didactic activities in which the teacher closely monitors the performance of their

students. To do this, the class is divided into smaller groups to improve both their concentration and performance, as well as the teacher's evaluation (Felício, 2018).

The game was created by students and for students, which makes the proposal appropriate to what several authors in the literature in the area address, that is, that the student is the subject of their own learning. Another advantage of building the game by the students themselves is the fact that they learn a lot when researching to prepare the questions and other elements of the game, and not just when playing, this fact being in line with Grossi (2017) which states that, when developing a playful methodology, the game itself is not its purpose, but it is the integrative axis between didactic content and the acquisition of information, which is effective through pedagogical actions of a playful nature.

Testing a recreational resource is important so that it can be improved and so that there are no unpleasant surprises when it is actually executed (Lozza; Rinaldi, 2017). Therefore, a test was carried out by the game's team, first only among its components and then with the other students of the subject, with suggestions to improve the game being noted.

FINAL CONSIDERATIONS

The game in question was designed and created to function as an auxiliary and facilitating tool in the teaching and learning process of analytical chemistry, within the scope of an introductory course in a higher education course in the health sector (pharmacy). However, its base structure adapts to other topics in chemistry and other subjects, requiring only the exchange of questions. It can also be perfectly applied and/or adapted to subjects from other courses in the health area (nutrition, nursing, etc.) or even from other areas such as engineering and exact and natural sciences.

The thirty questions created can be changed according to the syllabus covered and even this number can be increased to 45, 60 or any other amount you wish. As for the classifications of the difficulty levels of the questions, these can also be adapted to each class, by the teacher and/or students.

The game pieces were made quickly, practically and at low cost, a fact that further boosts their use. But they can also be made with other materials, as discussed before. Therefore, the result of this work is a tool with multidisciplinary applicability and easy access.

Therefore, the target shot of analytical chemistry can be applied to competing groups or students competing to reach a single winner, encouraging the search for knowledge through the competitive spirit in didactic games, which provide students, and why not the teacher as well. ? Fun moments in class and great learning.

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