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Chemical Battleship: Discovering and Learning the Periodic Table Playing a Didactic and Strategic Board Game

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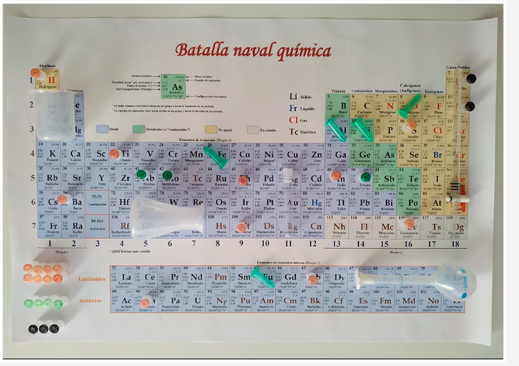
ABSTRACT: The periodic table is an essential topic in the teaching and learning of science at all education levels, as it contains information about the main physical and chemical properties of the different elements constituting the matter. However, becoming familiar with the facts behind the periodic table such as the element names and/or symbols, their metallic character, their electronegativity, and so on, may seem a tedious and boring task, depending on the approach the teacher uses. One way to stimulate students is through so-called gamification, in which learning occurs as an "almost undetected" consequence of playing a game. Of course, the game must be designed and prepared in such a way that the game and learning come together. In this work, we present Chemical Battleship, a chemical version of the classic board game Battleship, to learn the main topics contained in the periodic table and identify the common glassware of the lab. Additionally, using this game facilitates presenting the chemistry from a fun approach to certain educational levels. The periodic table itself is used to deploy the "fleet", which is actually just labware. The "shots" must be "fired" by identifying the chemical element the player wants to fire at, and they must do so by using different properties of the element. Repeating this process, students get soon familiar with the periodic table and the information it contains, as well as with the lab glassware. Chemical Battleship was tested with elementary school students and third-year students in a Primary Education Teacher Degree program. Use of this game had a high acceptance from both groups, awakening students' interest and curiosity in the first group and improving knowledge in the latter group. Students enhanced not only their subjective perception of their knowledge but also what they really know about the periodic table, as reflected in the improvement of their marks.



KEYWORDS: *Elementary/Middle School Science, High School/Introductory Chemistry, First-Year Undergraduate/General, Laboratory Equipment/Apparatus, Physical Chemistry, Collaborative/Cooperative Learning, Humor/Puzzles/Games, Atomic Properties/Structure, Nomenclature/Units/Symbols, Periodicity/Periodic Table*

The most common and widely used tool to access information about the chemical elements (name, symbol, aggregation state, metallic degree, atomic number, oxidation states, electronegativity, electronic configuration, etc.) is, doubtless, the periodic table (PT). Therefore, this tool becomes an essential subject in the teaching and learning of science at all educational levels. However, learning this information by heart becomes easily a tedious, mechanical, and poorly attractive activity for the students,[1] especially the youngest ones.

One of the forms of engaging or stimulating them is the so-called gamification, understood as the use of games or hands-on activities that mix enjoyment and learning.[2−8] Many examples in the literature approach periodic table concepts in a fun way for students: card games,[9−14] board games such as Taboo[15] or bingo,[12,16] crossword puzzles,[17−19] building blocks,[20,21] group dynamics,[22] or sport-related games.[23,24] However, to our understanding, these proposals are of limited application in certain educational levels, as all of them fulfill at least two of the following items:

- The content of the periodic table that are dealt with in these games are mostly the name, chemical symbol, and/or atomic number. Only few cases include other physical and chemical information.[10,23]
- The game does not include all of the elements. Most of them use only the representative ones (blocks *s* and *p*).
- Playing requires a great deal of materials that must be printed or obtained, which is often difficult to prepare.
- The game rules are too numerous or confusing, making the game difficult to play sometimes.

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- With a few exceptions,[13,19,20] these games are initially designed and described for upper-level students, mainly in high school or in undergraduate education.

In this work, we describe Chemical Battleship, a game based on the popular board game Battleship that uses the periodic table as a game board and labware as ships. It is designed to be playable by students from primary education (middle schoolers) to first-year undergraduates, and it allows working with different content of the periodic table as well as with other chemical contents, according to the education degree in which the game is played.

The idea of pretending to battle in the classroom to learn chemistry has already been proposed in Orbital Battleship;[25] that game, however, focuses on high school and first-year undergraduate students and specifically aims to reinforce knowledge of the atomic structure by playing with the energy subshells of the atoms. The aims, scope, and mechanics of Chemical Battleship are more general. This game is designed for students to learn about the periodic table, everyday chemistry, and to get used to labware. Additionally, it can be used as a tool for a first fun approach of young students to chemistry. This work describes how the game can be used with different educational levels, from primary school (middle school grades) to university students.

Chemical Battleship was tested with elementary school students (from 8−12 years old) from regional schools and with Primary Education Teacher Degree students at the University of Oviedo.

■ ACTIVITY OVERVIEW

The simple fact of using a game to learn chemistry shows a series of advantages, which are characteristic of this kind of tool. We have found that gamification has the following effects:

- Catches students' attention[26] to work on chemistry content. That is seldom easy, especially at certain educational levels where students lack interest in the experimental sciences.[27−29]
- Shows that learning through nonconventional and playful methods is possible.[2,4,6,30] Moreover, using uncommon educational instruments often yields a good reception from the students.
- Increases motivation[12,13,31] and concentration.[14,22,32] The competitive character of the game awakens students' interest and, as a consequence, increases their concentration in order to win.[23−25]
- Encourages teamwork[24,33] through the development of strategies and consensus decision-making, since every student on the team has the same common goal: win the game.

Chemical Battleship may be played with different knowledge aims depending on the educational level of the students. As briefly described below, some understanding of the periodic table is necessary in order to play, both to choose and deploy the "ships" (see attacking-fleet cards and fleet-deploying cards) as well as throughout the game (see the Rules and Development section). In the case of elementary school students and first-year high school students (ranging 8−13 years), the main aim is awakening their interest in science by approaching chemistry in a fun way, getting them used to the periodic table and learning some of the fundamental topics:

- How many elements exist
- How elements are sorted by a growing number which identifies them
- The existence of three different types of elements: metals, nonmetals, and semimetals
- The possibility of finding elements in any of the three aggregation states of matter under room temperature conditions

Additionally, the young students playing Chemical Battleship can learn the name and symbol of the simplest and common elements, C, H, N, O, ... Moreover, they learn the names of many of the common labware elements of the scientific laboratory (see the Materials section). Table S1 in the Supporting Information contains content articulations for the remaining educational levels.

■ MATERIALS

Chemical Battleship is played in two teams, the green team and the blue team. Each team needs the following materials: a game board, laboratory ware, and game cards (these include information cards, attacking-fleet cards, and fleet-deploying cards, all described below).

The Game Board

The game board or battle board is 50 × 75 cm^2. The board must be a periodic table specifically designed for the game, where every element is a 3.8 cm square so the positioning of ships is easy. The table must include the 118 elements nowadays accepted by the International Union for Pure and Applied Chemistry.[34] Every square contains the following information: name, chemical symbol, atomic number, atomic mass, aggregation state at room temperature, metallic degree, density, melting point, Pauli's electronegativity, the most common oxidation states, and electronic configuration.

Laboratory Ware

The various pieces of laboratory ware take the role of combat ships in the fleet. We have chosen the most common elements in a chemistry laboratory with the proper size and shape to be easily deployed in the board (Figure 1) and which mimic the different ships in the original Battleship game. In order to minimize risks, we strongly recommend using plastic ware instead of glassware. The fleet of each team is constituted by

- 5 Eppendorf tubes

Figure 1. Labware used as "ships". Color stoppers are used to mark the shots. See the details in the text.

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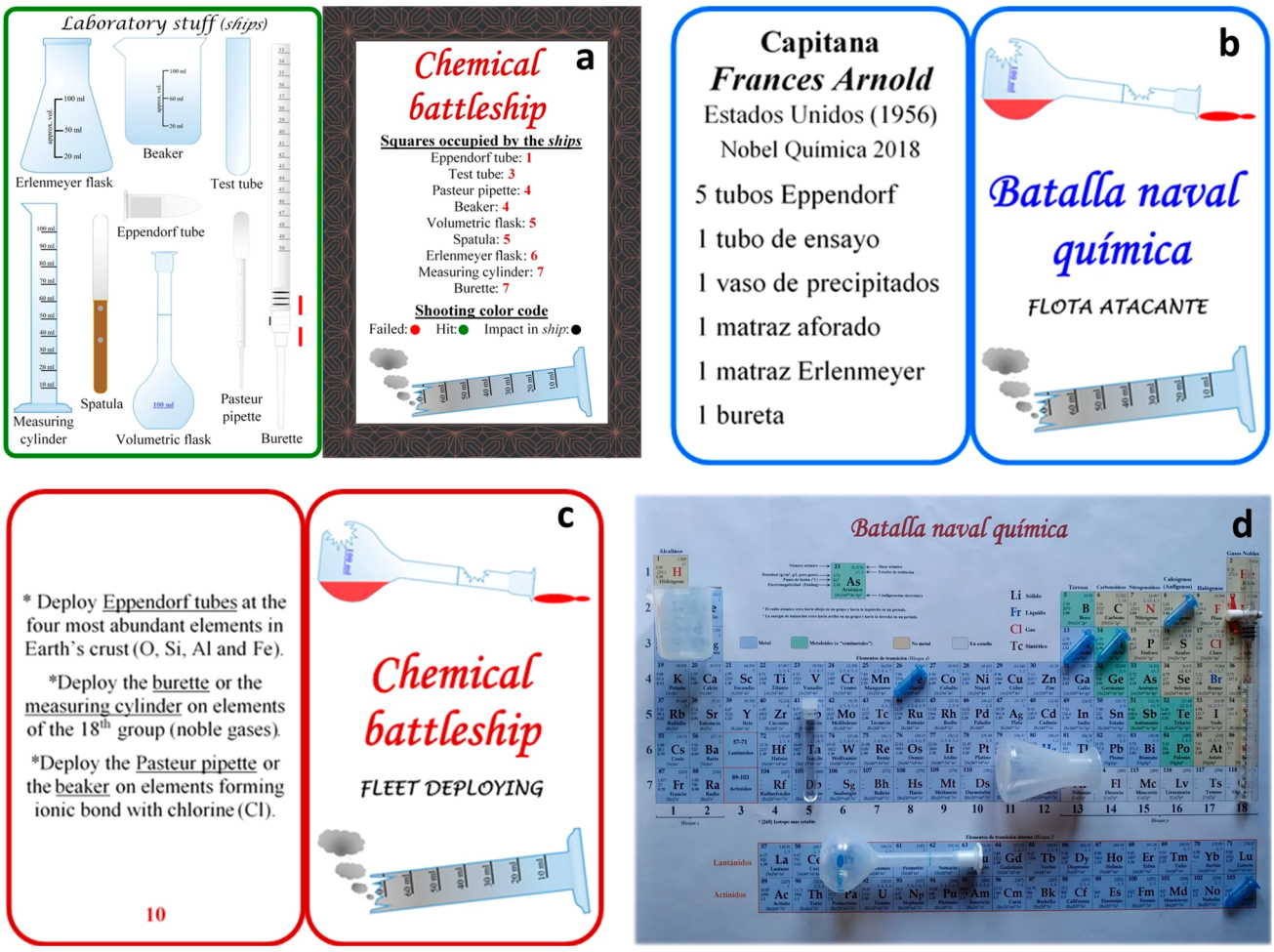

Figure 2. (a) Two sides of the information card; (b and c) example of the two sides of an attacking-fleet card (blue team) and a fleet-deploying card; (d) one possible distribution of the attacking fleet following the instructions of the fleet-deploying card shown in part c.

- 3 test tubes with plastic stopper
- 1 Pasteur pipet
- 1 100 mL beaker
- 1 100 mL volumetric flask
- 1 laboratory spatula
- 1 100 mL Erlenmeyer flask
- 1 100 mL graduated cylinder
- 1 buret cut to size to fit the game board

Additionally, every team needs colored stoppers:

- 50 red stoppers to mark the failed shots
- 30 green or blue stoppers to mark successful green or blue team hits
- 10 black stoppers to mark the hits on a team's own ships

If colored stoppers are not available, normal ones can be properly decorated with color stickers and/or painted. Alternatively, lacking stoppers, players can use color clips or print an additional A4-sized periodic table, plasticize it, and mark the shots and impacts there with nonpermanent ink.

Game Cards

The battle board and the three kinds of cards are available both in Spanish- and English-language versions in the Supporting Information.

Information Cards. One side of the information cards contains images of the lab material used in the game, together with the corresponding names. The other side details how many squares (elements) every ship occupies as well as the color code used to mark the shots with stoppers (Figure 2a).

Attacking-Fleet Cards. The attacking-fleet cards reveal which ships, from all of the existing ones in the fleet, will be used for attack in every game. Each team will use a different card. Both teams have six different attacking-fleet cards with the same size (30 squares/elements), each of which is "commanded" by a historic well-known chemist so as to familiarize students with these chemists. The blue team commanders are Ada *Yonath*, Amadeo *Avogadro*, Antoine *Lavoisier*, Dimitri *Mendeleev*, Frances *Arnold*, and Marie *Curie*. The green team commanders are Dorothy *Hodgkin*, Humphry *Davy*, Irene *Joliot-Curie*, John *Dalton*, Linus *Pauling*, and Rosalind *Franklin*.

The main aim of these cards is to help students learn and identify the different laboratory ware of a chemistry lab (with the help of the information card if necessary). An example of an attacking-fleet card is shown in Figure 2b.

Fleet-Deploying Cards. The fleet-deploying cards are common for both teams and contain instructions about positioning some of the "ships" of the attacking fleet in the board. A total of 24 cards are distributed among the different educational levels, attending to the chemistry content taught at each level. Primary education and first-year high school students play with cards 1−6. In order to maintain students' attention and interest, these cards have fewer instructions related to the name,

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symbol, metallic character, and aggregation state of the elements.

The cards needed for other educational degrees are indicated in Table S1 in the Supporting Information. Nevertheless, a teacher may also decide to use cards of lower education levels in order to refresh previous knowledge, depending on the level of the students or review topics to strengthen. The ships of the attacking fleet that do not appear in the cards can be freely deployed in the battle board. Parts c and d of Figure 2 show an example of a fleet-deploying card and a possible positioning of the ships following the card's instructions.

RULES AND DEVELOPMENT

Students are divided into two teams, each with 6−8 players. Each team sits around a different battle board, which must be situated in different tables, away from each other. Teams have the previously mentioned labware (the fleet), the information cards, and their deck of attacking-fleet cards. The fleet-deploying deck is handled by the teacher. The development of the game takes place in the following steps:

1. In order to situate the ships in the board, each team will have several minutes, controlled by the teacher, to do *both* of these actions: (i) randomly choose an attacking-fleet card and take the corresponding labware and (ii) randomly choose a fleet-deploying card and follow its instructions (Figure 2d).
2. The teacher sets out a question related to the periodic table. The first team to answer correctly starts the game as the attacker. Table S2 of the Supporting Information includes some example questions for every educational level.
3. The attacking team must identify which element they are firing at by providing information about it, which depends on the educational level, focusing on the content intended to be reinforced. In the primary education (middle school) and first year of high school education levels, the attacking team must indicate the name and number of the element being shot. Check Table S1 in the Supporting Information for other educational levels.

   If the attack is successful (students "hit" some of the labware—ships of the other team), they go on firing to destroy the ship. If they fail, the defending team now becomes the attackers. The attacking team marks their board with hits (green or blue stoppers); failed hits are marked with red stoppers.
4. The team that receives the shot has to indicate whether it has failed, saying "miss"; hit, saying "hit" if it is not completely destroyed; or "sunk" if the ship has been hit in all of its squares. Hits must be marked with black stoppers. When a ship is "sunk", it must be shown to the attacking team and withdrawn from the board with its corresponding black stoppers.
5. The game is over when one of the teams has sunk all of the labware of the other team, when both teams spend 50 failed shots (red stoppers), or after a predefined number or rounds or time (typically 15−20 min) in order to avoid very long games.

The game requires little supervision and participation from the teacher. Teachers may help the students with the indications in the fleet-deploying card in such a way that the learning process becomes a part in the game itself.

PLAYING THE GAME

Chemical Battleship has been tested with students at two different educational levels: elementary school students from different school centers of the region and third-year students in a Primary Education Teacher Degree program at Universidad de Oviedo (Asturias, Spain).

Play Testing with Middle School Students

The development of the activity with elementary school students was carried out in collaboration with the *Unidad de Cultura Científica e Innovación* (Unit for Scientific Culture and Innovation, UCC+i) of the Universidad de Oviedo in two sessions during the Spanish Science Week (November 2018), with 150 students in the 8−12-year-old range chosen from four schools from different parts of Asturias. Due to the high number of participants and to the limited time for the development (1 h per school), they played with teams containing 6−8 people and used a *fast version* of the game consisting of a shortened length of 10 min and discarding the use of the cards for choosing or deploying fleets. A plasticized auxiliary periodic table as well as nonpermanent ink markers for noting the shots were used. Furthermore, all of the fleet was used, with two aims in mind: (i) allowing the students to get used to the labware and (ii) maximizing the probability of impact, thus increasing students' motivation. Colored Eppendorf tubes were chosen to gain the attention of the youngest players.

At the beginning of the session, the teachers explained that the elements are sorted according to a number, which grows toward the right and down in the periodic table, just like a book is read in Spanish and English. They explained the color code (metallic character and aggregation state) too, as well as the basic game rules. In order to fire, the students only needed to say the (atomic) number (it was not necessary to expressly state that it was the atomic number) and the name of the element.

On some occasions, the teachers had to help students find the element in the table in order to speed up the game, thus having more "shooting rounds". In every game played, at least one ship was sunk, eliciting a joyful and raucous response among the students.

Play Testing with Primary Education Teacher Degree Students

The test with university students took place along with courses in 2018−2019 and 2019−2020 in the subject "Didactic of Experimental Sciences" in the third year of the degree, having a very similar development for both courses. The test was repeated six times during five working days (the same week), in all of the practical sessions. Sessions were 1 h long and with 12−18 students each. The previous week, the students were informed that in the forthcoming session a novel version of the game Battleship was going to be used to look over some of the information about the chemical elements shown in the subject. In every session, there was a first round with open questions and simple exercises to review the contents meant to be worked along the game (atomic and mass numbers, Z and A, the electroneutrality of the atom (same number of protons and electrons), types of chemical structure, or types of chemical bonds). The game itself was played in the last 15−20 min of the session. The students were distributed into two teams with a similar number of people, and the material was delivered to the students by the teacher. Before starting, the basic rules and development of the Battleship game were introduced to those students requiring so.

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Taking into account the topics of chemistry in the curriculum of the subject, only the deploying-fleet cards 7−14 were used. Once every team had chosen the attacking-fleet card and the fleet-deploying card, the students had a few minutes (typically 3−5 min) to deploy all of the "ships". The teacher checked whether the students placed the ships following the instructions properly and took advantage of the situation to remind students one more time about some chemical content. During the attacking phase, the spokesperson of the team must indicate the name, chemical symbol, metallic character, and atomic number of the element that is being shot at. A game length of 15 min allowed each team to shoot about 25 times, although the whole fleet of a team was sunk only once.

GAME ANALYSIS

Reception by the Middle School Students

The pupils really enjoyed the idea, showing an increasing interest in the periodic table, laboratory ware, and participating in a very active way. Their interest was evident in the conversations held among them as well as in those held with their teachers, or in the questions that they raised. The names of some of the elements were familiar to them (usually from TV commercials), and they established associations between the labware and some daily tools. This situation was taken advantage of by the teachers to introduce to the students some daily chemistry facts by relating them with the information contained in PT: there are metals such as the calcium of bones or the aluminum of cans of soda, semimetals like silicon of microelectronic components, and nonmetals like carbon, essential for life; most of the elements are solids, but there are some gases like the oxygen we breathe or liquids like mercury, formerly used in thermometers; some elements are not present in Nature and can be obtained only in laboratories, having a lifetime of just a few seconds or even less. Most students were surprised by the "huge" amount of metals, about the fact that some of them are liquid at room temperature, and the "weird names" of some of them. The students' inherent curiosity and their eagerness to question helped them learn and meet the world of chemistry without realizing it.

The game was also useful for practicing some very important principles at that age, such as collaboration and respect for colleagues, since they had to agree how to deploy the "ships" and where to fire. Additionally, shooters rotated so that every member of the team held the position.

Reception by the Primary Education Teacher Degree Students

The activity had a good reception among the third-year Primary Education Teacher Degree students for the two years it was carried out. During the development of the game, the students agreed on the deploying position of the ships as well as the aimed element of every shot. They rotated to provide the information on the shot, so they were continuously using terms such as metal, nonmetal, atomic number, covalent bond, ionic bond, diatomic molecule, the name and the symbol of elements, etc., thus reinforcing their knowledge without even realizing it. Additionally, some students acted as "teachers", resolving questions raised by some of their teammates. Students learned from their own colleagues, establishing *cooperative learning*.[35,36] The atmosphere of interest aroused during game play was taken advantage of by the teachers to raise questions related to the facts presented in the beginning of the session (e.g., difference between A and Z, how to know the number of electrons of an element from the Z number, how to calculate the number of neutrons of an element), to reinforce them. Furthermore, the students wondered and asked several curious questions such as why the denomination "metalloid", where do some names of elements come from, which were the characteristics of some synthetic elements, or what some of the elements were used for.

SATISFACTION OF THE STUDENTS WITH THE ACTIVITY: DATA COLLECTION

Feedback from Middle School Students

The idea behind playing this game with the primary school students was to have them approach chemistry from an attractive and playful perspective, trying to awaken their scientific vocation.

At the end of the activity, the students could indicate their satisfaction degree using color stickers—green, high satisfaction; yellow, medium satisfaction; red, poor satisfaction. In the final results, a clear positive valuation is evident: 4% red stickers, 16% yellow stickers, and 80% green stickers. This agrees with the verbal comments of the students, who revealed that they found Chemical Battleship fun and that the game sparked their interest. The teachers of the students were also greatly impressed with the game, and they demonstrated a clear predisposition to use it in the classroom, inquiring where they could get the material. Some of the teachers even stated that they were wanting to imitate the idea and apply it to their classes.

Feedback from Primary Education Teacher Degree Students

In this case, the ideas behind the use of Chemical Battleship are to (i) review chemistry concepts and learn about the lab equipment and (ii) show preservice teaching students a new tool that they could use with their future pupils to show them a fun and easy approach to learn chemistry. According to the following described results, we think that both aims were successfully achieved. The first interesting success obtained with the activity was an increase in the number of students attending the sessions in the week when Chemical Battleship was played due to a "pull effect". In fact, more people attended at the end of that week than the first days of the week.

Also, the use of Chemical Battleship in the classroom seems to have had a positive effect in improving students' answers regarding chemistry. During the experimental science lab lessons that took place one month later, about one-third of the students claimed to be able to identify the labware thanks to having used them as "ships" in the game. This percentage is greater than that of previous years, when only about one-tenth knew the name of the lab equipment at the beginning of the practical sessions. The students themselves blamed this ignorance on their selection of a nonscientific option in their Baccalaureate. Likewise, an exercise consisting of filling out a form, similar to the one shown in Figure 3, was included in the final test of the subject in the course 2018−2019 (the students could use a periodic table to know the symbol of the element). In order to answer properly, the students need to understand numbers Z and A, the electroneutrality of the atom, as well as how to find an element in the periodic table when Z is known. All of these aspects were practiced in the sessions in which Chemical Battleship was played.

Therefore, the success of the use of the game was estimated by comparing the correct answer rate with that of students of previous years, who did not play the game (control groups), who answered a similar question in their final examinations.[37] That

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Element	Protons	Electrons	Neutrons	Z	A
		6	8		
$^{56}_{26}Fe$					
			17	16	

Figure 3. Example of an exercise of the final test, related to the content worked on during the game sessions of Chemical Battleship.

comparison is shown in Table 1. It is clear that the percentage of students answering correctly rises when compared to the control groups. Similarly, the number of students with three or more mistakes also decreased in the Chemical Battleship group compared to the control groups. Table 1 also includes students who failed just one or two cells. This information is included, since we consider that these mistakes comes from numeric fails rather than conceptual errors (as an example, some students properly calculated the mass number in two different rows and failed in the third one). However, three or more fails indicates a conceptual error (such as wrongly calculating the mass number in every case, estimating the number of electrons from the number of neutrons every time, exchanging *A* and *Z*, etc.).

Table 1. Comparison of Correct Responses on Test Questions Relating to the Periodic Table

			Number of Wrong Answers (%)		
Academic Year	*N*	Answers All Correct (%)	1	2	3[c]
2015−2016[a]	90	71	8	2	19
2017−2018[a]	69	74	3	6	17
2018−2019[b]	130	85	5	2	8

[a]These students served as the control groups; see the text discussion for details. [b]These students are the treatment group who played Chemical Battleship. [c]Students who had more than three answers incorrect are included in this category.

On the other hand, since the course offering in 2014−2015, some other playful materials were used throughout the academic year to increase the students' motivation and interest in chemistry and physics. These materials included dynamics to learn about the chemical bonds,[38] scientific toys,[39] experiments, video games, crosswords, and word searches. In order to know the acceptation degree of these proposals, after the end of the course, the students were telematically asked whether they would use some of them with their future pupils. They had to choose among the answers "Yes", "No", or "I Don't Know", although they could include comments as they wished. In the course 2018−2019, 23 students answered the poll, whereas, in the next course (2019−2020), 29 students did. In both cases, the number of students represented about one-fourth of the students regularly attending the classes. Answers are summarized in Table 2.

Dynamics, scientific toys, and experiments are better valued as, according to the comments sent by the students, they are expected to be more appreciated and more enjoyable by their future pupils. Video games and word searches got the worst scores, as the students think that pupils already spend many hours at home playing video games and, in the case of the latter, because they are not novel and are overused tools. Regarding Chemical Battleship, which gets the second-best mark, the students who did not mark the affirmative option stated that they did not expect their future pupils to know the game Battleship. Although this may be a bit surprising, it has to be taken into account that some preservice students did not know the game Battleship either.

In addition to obtaining a high score (48.5 out of 52 possible, or ∼93%), the comments of the students about Chemical Battleship revealed that the game satisfactorily accomplished all of the proposed objectives, as they considered that it served as a motivating agent and it allowed them to learn and understand chemistry concepts. Moreover, they found this game to be an optimal tool to teach chemistry to their future pupils. The comments sent by the students are recorded in Table S3 in the Supporting Information (original comments in Spanish are included as well).

EVALUATION

Taking into account the observations of the authors during the development of the different games and the feedback from the participants as well as the results shown in the previous section, we can state that the use of the Chemical Battleship game provides a playful way to learn about periodic table chemistry concepts and eases also a series of *educational goals*, regardless of the educational level of the participants. Despite the fact that winning was far from being the final aim of the game, the victory represented the perfect reason to play, and this competitiveness increased the motivation and the concentration in the game: the

Table 2. Comparison of Preservice Student Responses Indicating Their Valuation of Using the Playful Tools Presented in the Courses with Their Future Pupils

	Number of Students Responding in Each Answer Category						
	"Yes"		"I Don't Know"		"No"		
Statement for Response with Tool Options: "Would you use some of these playful tools with your future pupils?"	18−19[a]	19−20[b]	18−19[a]	19−20[b]	18−19[a]	19−20[b]	Final Score[c]
Dynamics to learn about chemical bonds	22	29	0	0	1	0	51.0
Chemical Battleship game	19	28	3	0	1	1	48.5
Scientific toys	21	29	2	0	0	0	51.0
Experiments	22	29	0	0	1	0	51.0
Video games	14	25	6	2	3	2	43.0
Crosswords puzzles and word searches	15	24	4	1	4	4	41.5

[a]Academic year 2018−2019; *N* = 23. [b]Academic year 2019−2020; *N* = 29. [c]Scores were tabulated based on "Yes" = +1.0, "I don't know" = +0.5, and "No" = +0.0.

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players were at every moment focused on the chemical information given when shooting, either to know whether they hit or to detect whether they were hit. Additionally, the game promoted student interaction and teamwork, as the decisions had to be agreed upon within the team both for the initial distribution of the fleet in the board and for choosing the positions of the shots. Complementarily, the game prompted players to develop game strategies in order to hinder their opponent's task and make their shots more effective (e.g., avoid placing ships in adjacent positions, distribute the ships all over the board, probe the opponent's whole board with your shots, decide about the direction of the hit enemy ship, etc.). An additional advantage of the game is its straightforwardness, both in the preparation and during the development, since the only thing that the players need to know in order to be able to play is to interpret correctly the information presented in the periodic table. The chemical knowledge of the players becomes reinforced every time they play, since, otherwise, there is no possibility of playing and, therefore, there is no fun.

This activity has been well received, which is particularly noteworthy because the background of the students in the Primary Education Teaching Degree program in Spain is mainly (70%) in the humanities and they often have a low level or negligible knowledge of science.[40,41] Furthermore, many of them showed a negative predisposition to science subjects arguing that they do not understand them and showing a general lack of interest.[42,43]

Taking all of this into account, the game demonstrated accomplished the initial objectives proposed by the authors at both educational levels.

CONCLUSIONS

In this paper, we have described Chemical Battleship, a board game designed to teach students and review with them periodic table concepts, to help them acquire chemical knowledge and become familiar with labware using a playful approach. The game was created to be usable at different educational levels, and it does not require materials beyond those commonly available in a typical school lab and a few easily printable documents. The game was successfully tested with primary school (middle school) students and with Primary Teacher Degree students.

For the youngest students, Chemical Battleship proved to be an excellent introduction to the periodic table and some labware, as well as a fun approach to chemistry, awaking their interest and making them wonder about science.

For the university students, using the game translated into a higher attendance of the subject and an opportunity to review chemical element concepts presented in the theory lessons in a different and entertaining way, which resulted in an improvement in their academic marks. In addition, Chemical Battleship was considered to be a quite useful and interesting tool too, which they could use with their future students to supplement the usual routine of science lessons. Moreover, Chemical Battleship increases students' motivation and their focused concentration, enhances their respectful interaction, and improves cooperative and teamwork abilities while they also develop strategic skills.

In our opinion, the results obtained with Chemical Battleship are highly satisfactory at both educational levels, achieving the objectives planned during its design.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.0c00553.

English- and Spanish-language versions of the Chemical Battleship game materials, ready-to-use in PDF format: periodic table as battle game board; different game cards (information cards, attacking-fleet cards, and fleet-deploying cards); information about playing the game at different educational levels; student comments on Chemical Battleship (ZIP)

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Notes

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