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Playfulness in the classroom: Gamification favor the learning of pharmacology

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Abstract

In recent years, growing interest has been seen in the application of gamification in education, which can be defined as the application of game design elements in learning activities. The goal of gamification is to motivate students by creating an engaging learning experience that can keep them focused on learning tasks in the classroom. However, gamification is a major challenge for education, particularly in higher education institutions. The present work presents 11 gamification activities for teaching pharmacology in a medical course. The moment at which the activity fits best in the class, the ways in which the activity can be applied, and the advantages and difficulties that are associated with each game in the classroom are presented. We report student evaluations of the gamification learning activities. The use of these games fosters learning, increases academic engagement, and makes classes more enjoyable.

Keywords Active methodology · Education · Game · Meaningful learning · Medicine

1 Introduction

Teaching the basic discipline of pharmacology occurs in several contexts, including medicine, nursing, pharmacy, dentistry, physiotherapy, and veterinary medicine. In health science educational curricula, a competency-based approach underlies decisions about how pharmacology is incorporated into the curriculum, which aspects of pharmacology are taught, and which learning tools are used (Al-Fageh et al. 2018). To improve learning rates, pharmacology teachers must be academically qualified in their specialized disciplines. They also must have practical knowledge about general

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teaching methods. However, such qualification and methods alone are insufficient. A large gap can exist between knowing a topic (i.e., content knowledge) and knowing how to teach and learn it (i.e., pedagogical content knowledge; Bucat 2005). Some knowledge about teaching and learning in pharmacology is specific to the subject in question (Landers 2014). Thus, pharmacology courses should include the development of contextualized learning and not just the mere memorization of facts (Landers 2014; Gotardelo et al. 2017).

The benefits of meaningful classroom learning experiences are easily recognized. When working with this methodology, good results appear from the first day of class, even for students with learning difficulties. One factor that substantially contributes to meaningful learning is collaborative work, which makes students adopt a new approach to perform a task. Such students have fun while learning, are motivated, enjoy performing tasks, deliver necessary materials, and are satisfied with their educational experience. The teaching task is also dramatically different, and teachers can save much effort by using this tool to introduce students to long-term learning. Additionally, when teachers from all areas and educational levels perceive the progress of students and resulting products, they also feel motivated to continue, find meaning in teaching, and experience rewards of their educational efforts (Amrein-Beardsley 2008).

Given this positive outcome for both students and teachers, education in terms of meaningful learning should be encouraged. Several teaching strategies can be used by teachers to facilitate meaningful learning, such as using games. Gamification has become a popular technique that can be applied in various contexts to motivate students to engage in specific behaviors, thus improving learning (Landers et al. 2015). Research projects have compared gamified vs. non-gamified learning contexts and found that any learning gamification strategy can produce desirable results for students, depending on the specific elements of the game and contexts in which they are used (Landers 2014).

Thus, the approach of gamified learning through active teaching methodologies can favor learning in several higher education disciplines, including pharmacology. However, few studies have reported teachers' experiences in using gamification to teach pharmacology. Thus, the present work can help fill this gap by specifying the detailed application of this methodology in the classroom by teachers to promote greater student engagement and learning.

2 Materials and methods

2.1 Gamified methods to teach pharmacology

Gamified techniques that were used to teach basic pharmacology in a medical course at Universidade Paranaense (UNIPAR; Umuarama, PR, Brazil) are presented. It is important to highlight that this medical school's curricular structure is composed exclusively of active teaching methodologies through problem-based learning and team-based learning, and this is the reason why we don't have a control group to pair the gamified learning of pharmacology through traditional teaching. We present the moment at which the activities fits best in the class, the ways in which the techniques can be applied, and the advantages and difficulties that are associated with each technique.

These information of each game were described by the teachers who prepare all games and used all methods. We evaluated and applied 11 games that can be used in the pharmacology classes. Game illustrations (Fig. 1) were designed by Freepik iconic bestiary.

2.2 Game of words

A playful representation of the game is shown in Fig. 1a.

a) When should the game be applied?

This method can be used at the close of the class after studying the topic material.

b) How should the game be played?

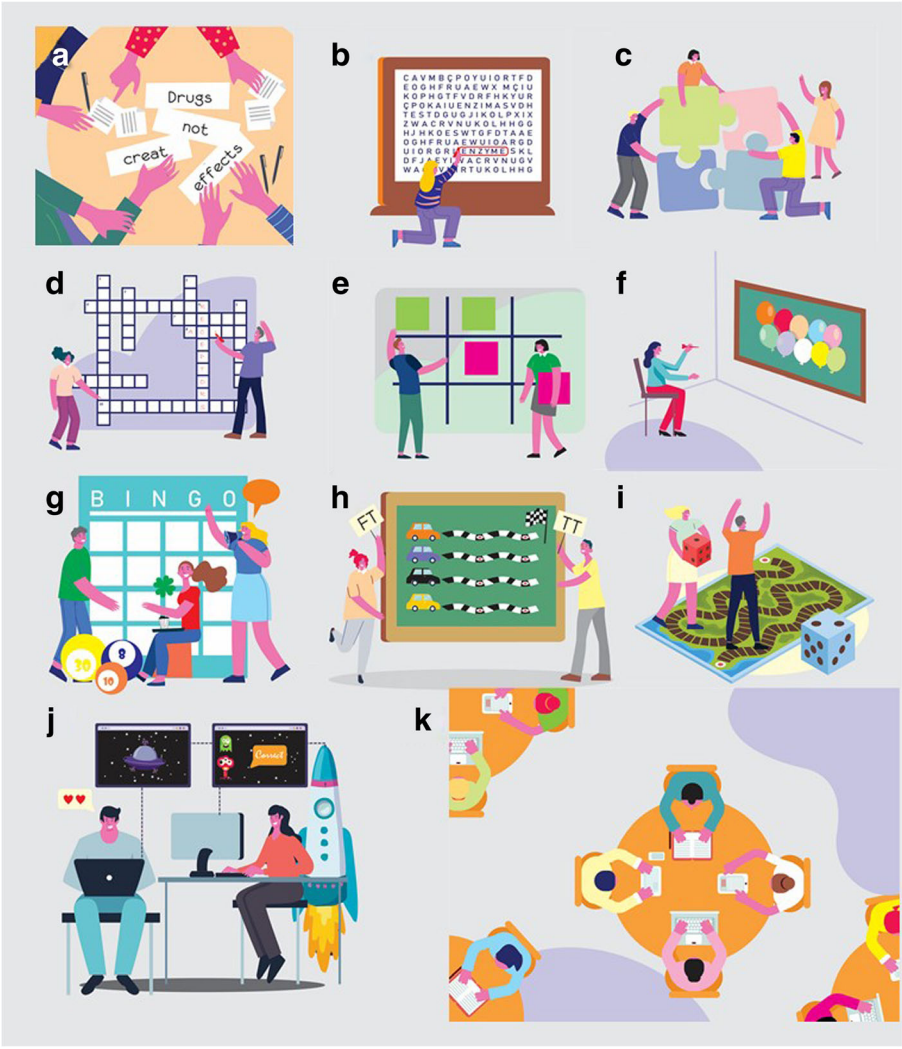

Fig. 1 Illustrations of games used to learn pharmacology. **a** Game of words. **b** Word hunting. **c** Puzzle. **d** Crossword. **e** Tic-tac-toe. **f** Target shooting. **g** Bingo. **h** Racetrack. **i** Trail. **j** Memorang. **k** Rally

For this game, the teacher writes two sentences, with approximately 20 words each, and prints them in large, legible font (e.g., Times New Roman, size 30). The teacher then cuts out the individual words of the two sentences, shuffles them, and delivers them in an envelope to each group of students. In addition to the envelope with the cut-out words, the teacher gives the student a blank sheet so that the group can assemble the words into sentences and paste them on the sheet. The teacher provides space for sentence 1, sentence 2, and the remaining words. The students work with the words and might form a sentence that is different from the one that is intended by the teacher. However, if the answer is correct, the teacher should consider it and present the student with another possible answer or, if sufficient time remains in the class, ask the group to try to devise a new sentence. The group that assembles the sentences correctly in the shortest time wins.

c) What are the advantages?

This activity promotes high student engagement. To assemble the words into sentences, the students must talk a lot about the subject and explain to each other why some sequences are not possible. Additionally, the cost of producing the material is low, and the activity is easy to prepare.

d) What are the difficulties?

There are no difficulties in preparing the material or applying the method in the classroom.

2.3 Hunting words

A playful representation of the game is shown in Fig. 1b.

a) When should the game be applied?

This activity can be used before class so that students know important keywords, thereby generating curiosity about the topic to be studied. The activity can also be used at the close of the class to memorize keywords that are related to that subject.

b) How should the game be played?

The teacher selects keywords that are related to the discipline of the class. The word search can be generated automatically on several sites that offer this service for free, such as Educolorir.com.

c) What are the advantages?

This activity holds students' attention and facilitates the memorization of keywords. Additionally, the cost of producing the material is low, and the activity is easy to prepare.

d) What are the difficulties?

This activity is performed individually and does not generate interactions between students or allow peer instruction. This activity does not develop critical reasoning about the subject.

2.4 Puzzle

A playful representation of the game is shown in Fig. 1c.

a) When should the game be applied?

This method can be used at the close of the class after studying the topic in the classroom.

b) How should the game be played?

The teacher assembles four puzzles, with four pieces each and themes that are related to the class. The ideal arrangement is not to assemble jigsaw puzzles with images but rather combinations of themes from the class. Students discuss the theme of the class and consequently revise the subject to assemble the sequences. The puzzles are assembled in PowerPoint, printed on sulfite sheets, and laminated to ensure that they can be reused. The teacher then shuffles the 16 pieces and gives them to the group of students so they can assemble the correct combinations. The group that assembles the four puzzles correctly in the shortest time wins.

c) What are the advantages?

This activity promotes high student engagement. To arrange the puzzle pieces, the students must talk a lot about the subject and explain to each other why some sequences are not possible. Additionally, the cost of producing the material is low, and the activity is easy to prepare.

d) What are the difficulties?

There are no difficulties in preparing the material or applying the method in the classroom.

2.5 Crossword

A playful representation of the game is shown in Fig. 1d.

a) When should the game be applied?

This method can be used before class so that students can study theoretical content before meeting with the teacher. This activity can also be performed at the close of the class to review and memorize content. Furthermore, the crossword can be used as a test question because it broadly addresses the content.

b) How should the game be played?

The teacher selects keywords and their respective concepts that are related to the subject that is being taught. A crossword puzzle can be generated automatically on several websites that offer this service for free, such as Educolorir.com.

c) What are the advantages?

Many crossword generation sites allow the user to generate several possible combinations of templates. Thus, each student can receive a different crossword puzzle with the same content. Additionally, the cost of producing classroom material is low, and the activity is easy to prepare.

d) What are the difficulties?

This activity is performed individually and does not generate interactions between students or allow peer instruction. Additionally, this activity does not develop critical reasoning about the subject.

2.6 Tic-tac-toe

A playful representation of the game is shown in Fig. 1e.

a) When should the game be applied?

This activity can be used at the close of the class after the topic is studied in the classroom.

b) How should the game be played?

The tic-tac-toe game board is created by the teacher with Styrofoam and covered with black paper. The game lines are white strips of bond paper. The students are divided into two teams that are assigned different colors. Each square has a question, but students will only know the question after choosing the square. After choosing the square, the teacher reads the question to the team and gives them a few minutes to answer. If the team answers correctly, then they place the color of their team on the square with a pin. If the team does not know the answer, then the opposing team can answer the question and place the color of their team on the square if they answer correctly. If neither team answers correctly, then that square is canceled, and the teacher instructs the next team to choose another square. The first team to fill a row, column, or diagonal with its color wins each round. The teacher assembles three sequences of tic-tac-toe games for each round, for a total of three rounds. The team that has the most wins in the rounds wins the game.

c) What are the advantages?

This activity promotes high engagement and generates good discussion among students about the subject of the class. The game also makes students acquire or perfect game strategies and employ emotional intelligence under supervision of the teacher. Additionally, the cost of producing classroom material is low, and the activity is easy to prepare.

d) What are the difficulties?

Creation of the tic-tac-toe game board may require a few hours of work by the teacher. There are no difficulties in applying the method in the classroom.

2.7 Target shooting

A playful representation of the game is shown in Fig. 1f.

a) When should the game be applied?

This method can be used at the close of the class after the topic is studied in the classroom.

b) How should the game be played?

The teacher elaborates seven questions on the subject. Each question is assigned a score, from 1 to 10, based on difficulty. Each question and its respective score is printed, cut out, and placed inside a balloon. Three other balloons in the game contain game elements, such as an extra score (e.g., win 3 points), pass a turn, or lose everything. The balloons are inflated and pinned to the board at equal distances from each another. A chair is positioned at a specific distance from the board in front of the balloons. Students are divided into two teams. The team chooses a player to sit in the chair and throw a dart to pop a balloon. When the paper falls from the popped balloon, the teacher reads the question and its score. After a few minutes of discussion, if the team responds correctly, then it accumulates that score. If the team does not know the answer or answers incorrectly, then the opposing team is given an opportunity to answer the question. If neither team answers correctly, then that question is cancelled, and the next team proceeds to pop the next balloon. The teams alternate in throwing the dart. If a team throws a dart but misses the balloons, then the turn is passed to the other team. If a team throws the dart and pops two or more balloons, then it loses its turn, and the teacher replaces the popped balloons. The team with the highest score wins after all of the balloons have been popped.

c) What are the advantages?

This activity promotes high engagement and generates good discussions among the students about the subject of the class. The game makes students acquire or perfect game strategies and employ emotional intelligence under supervision of the teacher. Additionally, the cost of producing classroom material is low, and the activity is easy to prepare.

d) What are the difficulties?

There are no difficulties in preparing the material or applying the activity in the classroom.

2.8 Bingo

A playful representation of the game is shown in Fig. 1g.

a) When should the game be applied?

This activity can be used at the close of the class or bimonthly because it tests several subjects within the discipline.

b) How should the game be played?

The teacher prepares 24 questions that are related to the topic of the class. Bingo cards can be generated on sites that offer this service for free, such as Bingobaker.com. On the card, the teacher inserts answers to various questions, and the website shuffles the answers, generating several cards with different sequences. Importantly, the answer must be just one word. For the game, students are divided into groups of 4 to 6 each. Each group receives a different card and beans (or other suitable markers) to mark the answers. The teacher takes a bingo ball and reads the question that corresponds to that number. The students must find the correct answer on the card and then places the marker on it. The group that first completes a row or column and says "Bingo!" wins. The teacher should check the answers to verify whether all are correct. If they did not answer all correctly, then the teacher disqualifies that group and continues the game until the top five groups remain (depending on the initial number of groups). The main objective of this game is to review class content. Thus, if some groups already completed a row or column but many questions have not yet been read, then the teacher can ask the students questions, regardless of the game, to further study the content.

c) What are the advantages?

This activity promotes high engagement and generates good discussions among students about the subject. The game makes students work as a team to arrive at the correct answer and employ emotional intelligence under supervision of the teacher.

d) What are the difficulties?

There are no difficulties in preparing the material or applying the activity in the classroom. The cost of this activity is low to medium, depending on the number of bingo cards the teacher buys.

2.9 Racetrack

A playful representation of the game is shown in Fig. 1h.

a) When should the game be applied?

This method can be used at the close of the class, bimonthly, or at the end of the term because it tests several subjects within the discipline.

b) How should the game be played?

To prepare the racetrack, the teacher sets up in PowerPoint a table with 12 columns (one for the starting line, eight for the study rounds, and one for the finish line). The number of lines includes one for scoring and one for each group (e.g., 9 lines for 8 groups). Each group is represented by a different car that is positioned on the start line of the racetrack. The teacher prepares 10 rounds with two statements each about the

class content. Affirmations can be true/true (TT), false/false (FF), false/true (FT), or true/false (TF). The teacher prints one answer possibility (TT, FF, FT, TF) on a separate sheet for each group. To perform the activity, students are divided into groups with four members each, and they receive four sheets with response possibilities. The teacher reads the two statements from the first round and gives the students a few minutes to discuss and choose the best answer. At the end of this time, the students raise the sign with the chosen answer, and the car of the team that answers correctly advances one space on the racetrack. If the team misses, then the car does not advance. The same procedure is repeated until the teacher has read the 10 rounds of statements. The teacher quickly resumes the content if the answers are incorrect. The team that reaches the finish line first wins.

c) What are the advantages?

This activity promotes high engagement and generates good discussions among students about the subject. The game makes students work as a team to arrive at the correct answer and employ emotional intelligence under supervision of the teacher. Additionally, the cost of producing the material is low, and the activity is easy to prepare.

d) What are the difficulties?

There are no difficulties in preparing the material or applying the method in the classroom. The teacher may lose a few minutes of class time to move the cars, but someone can serve as an assistant.

2.10 Trail

A playful representation of the game is shown in Fig. 1i.

a) When should the game be applied?

This method can be used bimonthly or at the end of the term because it tests several subjects within the discipline.

b) How should the game be played?

The teacher prepares a layout of a canvas track and a dice. The size of the trail and amount of data depend on available space and financial resources. For example, the track is printed on canvas (3 m × 4 m), and data (42 cm × 42 cm × 42 cm). The trail contains neutral houses (i.e., where the team stays at the house), question houses (i.e., where the team must answer a question for that house), and challenge houses [i.e., where the team is challenged with an physical activity, intellectual activity (such as sing a song or make a poem with the content of the lesson) or returns to the previous space]. For a 100-min class, the teacher prepares approximately 40 questions and 25 challenges. For the activity, the students are divided into two teams. A team member rolls the dice and moves that number of squares. If the team lands on a numerical square, then nothing happens, and the next team rolls the dice. If the team lands in a question

box, then the teacher reads the question and gives the team a few minutes to answer it. If the team answers correctly, then it stays in the house, and the next team rolls the dice. If the team answers incorrectly, then the team returns to the previous space. As there was no correct answer, the teacher explains the theoretical content to the class. If the team lands in a house with an challenge, they must perform the house challenge (e.g., singing a song or creating a poem about the theme of the class, doing jumping jacks, returning home, etc.). The team that crosses the finish line first wins. If the teacher does not have much time available for this activity, then the rules of the game can be modified (e.g., by allowing a team that answers a question correctly continue to roll the dice) so that the finish line can be crossed more quickly.

c) What are the advantages?

This activity promotes high engagement and generates good discussions among students about the subject. It is also fun and relaxing. The game makes students work as a team to arrive at the correct answer and employ emotional intelligence and creativity under supervision of the teacher.

d) What are the difficulties?

There are no difficulties in preparing the material or applying the activity. However, to perform this activity, a large physical space is required to accommodate the canvas with the trail and throw the dice. The cost for making the canvas and data is moderate to high, depending on the materials, but this difficulty can be overcome if the teacher draws the trail on the floor with chalk or even delimits the space with colored adhesive tape.

2.11 Memorang

A playful representation of the game is shown in Fig. 1j.

a) When should the game be applied?

This method can be used at the close of the class or bimonthly because it tests several subjects within the discipline.

b) How should the game be played?

Memorang (Memorangapp.com) is a study application for memorizing content that is used by thousands of students in more than 100 countries. The teacher creates a login and enters cards that are related to the subject, and the application creates from these cards multiple-choice questions, flashcards, correspondence questions, and intelligence games. The teacher makes the link available to the students, and the student can choose an avatar and start the studies within the modality that most identifies the student. Some students prefer multiple-choice questions, whereas others prefer intelligence games. However, when creating the games, the application shuffles the teacher's cards. Thus, the student sees the same subject, but it is asked in different ways several times, which

aids the memorization of concepts. The application also allows the student to monitor his performance and study at more advanced levels after completing more basic levels. The teacher can monitor the performance of all students who participate in the activity.

c) What are the advantages?

This activity retains students' attention and facilitates the memorization of keywords based on the class content. The game is remarkably similar to a video game, thereby generating substantial interest and engagement. By making the link available to all students, learning becomes exponential because students can access the content as many times as they want throughout the course to study that content.

d) What are the difficulties?

This activity does not develop critical reasoning about the subject because it is an activity that is intended to aid the memorization of content. Additionally, the application is only in English, which can be a limiting factor for some teachers and students. However, cards can be inserted in the teacher's and students' native language to overcome this limitation. Inserting cards can appear difficult when the application is first used by the teacher, but the application offers a tutorial that explains how to prepare material, which facilitates creation of the activity.

2.12 Rally

A playful representation of the game is shown in Fig. 1k.

a) When should the game be applied?

This game can be applied bimonthly or near the end of the term because it tests several subjects within the discipline.

b) How should the game be played?

The teacher prepares a test book with 100 multiple-choice questions that are related to the content that is taught over 2 months or during the term. Students are divided into four teams. For the activity, two classrooms are needed: one to answer questions (test room) and one for study (support room). In the test room, three participants from each team answer the group questions but without any consultation material. The other team members stay in the support room with consultation materials, such as books, handouts, computers, and cell phones. The activity lasts 1 h. During this time, the team members who stay in the test room and support room can be changed as many times as the team deems necessary. When changing rooms, however, they cannot take any consultation material or notes with them to the test room. The same student can return to the test room if the team wishes. One interesting aspect of this structure is that when leaving the test room and going to the support room to seek an answer to a question, the student can discuss it with the rest of the team, who helps him answer the question. The team that has the most correct answers at the end of the race wins. If there is a tie in the

number of correct answers, then the team with the highest number of correct answers and that finishes the race in the shortest time wins. After correcting the test, the teacher displays a map of the students' level of knowledge and highlights subjects that need to be studied again.

c) What are the advantages?

This activity promotes high engagement and generates discussions among students to answer the questions. The game also works on emotional intelligence of the students who need to work as a team under supervision of the teacher. Additionally, the cost of producing classroom material is low, and the activity is easy to prepare.

d) What are the difficulties?

There are no difficulties in preparing material or applying this activity in the classroom. However, to perform this activity, the teacher needs two classrooms, which could be a challenge, depending on the physical space of the institution. Additionally, this is an hour-long activity.

2.13 Students

Sixty-three students in the second year of the medical course at Paranaense University (UNIPAR, Umuarama, PR, Brazil) participated in this study. Their mean age was 21.9 ± 0.4 years. They were mostly female (66.2%) and in a course of graduation for the first time (88.9% versus 11, 1% in their second course of graduation).

2.14 Instruments of evaluation

An instrument that measured the effect of the pharmacology gamification approach on student achievement was developed. A total of 19 items (Table 1) were completed by the students. For the questions of Table 1, the response options were "strongly agree," "partially agree," "disagree," and "not observed." The questionnaire was applied after the end of all activities that were developed for pharmacology gamification.

2.15 Data analysis

The qualitative data are reported as frequencies and percentages. The effect of a pharmacology gamification approach on students' perceptions was investigated.

3 Results

The responses that were given by the students to questions about the pharmacology gamification activities are shown in Table 2. The use of gamification was favorably viewed as an active learning tool, in which 60.1% of the students answered "strongly agree" and 32.6% answered "partially agree" to all of the questions. A total of 92.7% of the students agreed with the proposed study method using gamification. The vast

majority of students strongly agree and partially agree that the inclusion of a gamification method improved the connection between theoretical content (90.5%) and allowed greater flexibility with the use of different styles to consolidate learning (81.0%). Gamification in the classroom also stimulated critical thinking through different types of activities (60.3%), improved the acquisition of pharmacology knowledge (63.5%), helped develop skills and attitudes (63.5%), favored integration with other students (65.1%), increased student participation (61.9%), improved memorization (71.4%), improved self-learning (74.6%), and held attention longer (66.7%).

The gamification method, according to more than half of the students, achieved the goal of teaching and learning pharmacology (54.0%), facilitated the memorization of theoretical content (58.7%), and was a stimulating activity (58.7%). However, in these questions, a large number of students partially agreed that learning objectives (42.2%), memorization (30.2%), and encouragement (33.3%) contributed to learning the content. A few students reported feeling uncomfortable in classes that used games (15.9%) or felt less able to ask questions during the games (14.3%). We also highlight that at the end of each semester we ask students to anonymously evaluate the discipline, through a digital platform, pointing out keywords that reflect the discipline's strengths. The most cited words were dynamics, games, creativity, innovation, didactics, relaxation, methodology and learning.

Table 1 Questions used to measure the perceptions of students who participated in pharmacology gamification activities from February to November 2019

	Question
1	Does the use of games achieve the goal of teaching and learning pharmacology?
2	Does the use of games allow flexibility and different learning styles?
3	Does the use of games stimulate critical thinking through different types of activities?
4	Was the use of games positive for the acquisition of pharmacology knowledge?
5	Does the use of games favor the development of skills and attitudes?
6	Was there a connection between the theoretical content and the content that was incorporated in the games?
7	Is the use of games appropriate for teaching pharmacology?
8	Did the use of games facilitate the memorization of theoretical content?
9	Did the use of games favor your integration with the other students?
10	Is the teaching approach with games generally stimulating?
11	Did using games increase your level of participation in class?
12	Does the use of games help build self-confidence?
13	Is the time spent teaching with games well spent?
14	Does the use of games emphasize learning memorized facts?
15	Is this teaching student-centered (more self-learning)?
16	Do you feel comfortable in class using games?
17	Does playing games encourage you to learn?
18	Do you feel free to ask questions during games?
19	Does using games hold your attention longer?

4 Discussion

With changes in views of modern specialties and increasingly open access to knowledge, education has become an experience in which students think about a subject as they interact with the instructor and each other. Therefore, the role of traditional teachers as information transmitters has evolved into a role as organizers and partners in student learning (Clapper 2009; Kudryashova et al. 2015). Teachers and students play an equally active role in the learning process. Active learning strategies refer to various collaborative activities in the classroom, ranging from real-world case simulations to collaborative problem-solving activities (Ercan 2004; Gelisli 2009).

In recent years, growing interest has been seen in the application of gamification in education, which can be defined as the application of game design elements in learning activities. The goal of such a learning strategy is to motivate students by creating an engaging learning experience that can keep them focused on the learning task. Gamification can be a major challenge for education, particularly in higher education institutions that typically have a traditional learning context, such as in medicine courses, which can be explained by the lack of training teachers to use this

Table 2 Feedback from students ($n = 63$) who participated in pharmacology gamification activities that were performed from February to November 2019

Question*	Strongly agree *n* (%)	Partially agree *n* (%)	Disagree *n* (%)	Not observed *n* (%)
1	34 (54.0)	26 (41.2)	3 (4.8)	0
2	51 (81.0)	10 (15.9)	1 (1.5)	1 (1.6)
3	38 (60.3)	21 (33.3)	2 (3.2)	2 (3.2)
4	40 (63.5)	20 (31.7)	3 (4.8)	0
5	40 (63.5)	20 (31.7)	0	3 (4.8)
6	57 (90.5)	6 (9.5)	0	0
7	30 (47.6)	29 (46.0)	3 (4.8)	1 (1.6)
8	37 (58.7)	19 (30.2)	6 (9.5)	1 (1.6)
9	41 (65.1)	19 (30.2)	1 (1.6)	2 (3.1)
10	37 (58.7)	21 (33.3)	5 (8.0)	0
11	39 (61.9)	16 (25.4)	6 (9.5)	2 (3.2)
12	26 (41.3)	28 (44.4)	5 (8.0)	4 (6.3)
13	31 (49.2)	30 (47.6)	1 (1.6)	1 (1.6)
14	45 (71.4)	18 (28.6)	0	0
15	47 (74.6)	15 (23.8)	1 (1.6)	0
16	29 (46.0)	23 (36.5)	10 (15.9)	1 (1.6)
17	31 (49.2)	27 (42.9)	4 (6.3)	1 (1.6)
18	24 (38.1)	28 (44.4)	9 (14.3)	2 (3.2)
19	42 (66.7)	14 (22.2)	5 (7.9)	2 (3.2)
Total	719 (60.1)	390 (32.6)	65 (5.4)	23 (1.9)

*For the list of questions, see Table 1. The data are expressed as the number of students (*n*) and relative frequency (%) of responses

methodology (Dicheva and Dichev 2016). The present findings may contribute to training teachers to use gamification to teach pharmacology. We presented 11 gamification activities and discussed how and when to apply them. Our goal was to facilitate the use of these techniques by the teacher and possibly inspire the creation of new games that can foster learning.

In medical education, an in-depth knowledge of pharmacology is necessary for effective pharmacotherapy and the rational prescription of medications. Although medication errors are multifactorial, knowledge about medications and prescription training are critical (Krähenbühl-Melcher et al. 2007; Engels 2018). Studies indicate that knowledge about medications among recently graduated doctors is insufficient. This weakness is related to a lack of knowledge about the pharmacology of prescriptions, which can contribute to medical prescription errors (Dean et al. 2002). In the present study, a high number of students reported that the use of gamification stimulated critical analysis, improved the acquisition of theoretical knowledge about pharmacology, and facilitated the memorization of content. Thus, gamified learning can help improve pharmacology learning rates and lead to more rational and safer therapeutic prescriptions.

Pharmacology classes should promote the development of contextualized learning and not merely the memorization of facts (Gotardelo et al. 2017; Landers 2014). In fact, the content of pharmacology classes could be reduced. Traditional (expository) classes should be reserved only for those situations in which the systematization and synthesis of information are essential. Classes should be developed using active teaching and learning methodologies that consider the physical/motor, cognitive, emotional, and social dimensions of the students. Learning objectives should be based not only on acquiring knowledge but also on developing the skills and behavior that are required for future prescribers (Laing et al. 2001; Alexander 2008; Achike 2010; Silva et al. 2019). In the present study, there was a high level of student engagement in gamified pharmacology classes. Emotional, behavioral, and motor intelligence was incorporated into elements of the games, such as winning and losing, respecting the opinions of colleagues, engaging in teamwork for problem solving, decision making, and performing motor skills to participate in the games. Most of the students reported that the use of games favored the development of skills and attitudes, favored integration between students, increased participation, and improved attention.

The success of any teaching gamification activity depends on effective instructional material and content. The goal of gamification is not to replace traditional instruction—it is intended to improve it. If instructional content does not help students learn, then the gamification of content cannot, by itself, result in effective learning. Furthermore, the effect of behaviors and attitudes about learning also reflects the theory, which can create substantial differences in learning, although the degree to which these attitudes and behaviors are impactful varies according to the specific construct (Silva et al. 2019). Using the techniques that are proposed in this study, theoretical content is accessed in a gamified manner, which allows students to access such information in different ways, thereby favoring the consolidation of learning. Most of the students stated that there was a connection between the theoretical content and content that was incorporated into the games, thereby favoring learning and not simply being a fun activity for the students.

Despite all the scientific evidence that gamification favors student learning, reports on how the teacher can apply it in the teaching of pharmacology are still scarce. Much is known about the positive impact of active teaching methodologies on student learning, but many teachers find it difficult to make the transition from traditional teaching to active teaching, due to lack of knowledge, lack of time to create the material or even out of self-doubt. In this way, the techniques described in this manuscript can help and inspire pharmacology teachers to use these games and create games that contribute to the teaching of this science.

In conclusion, the use of these games fostered learning, increased the students' engagement in the classroom, and made the classes more enjoyable. For many teachers and students, the theoretical subject of pharmacology itself is fun and exciting. However, perceiving new educational ideas and scientific developments in teaching and learning and incorporating them into face-to-face classes are innovative within pharmacology education.

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Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest in this research.

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