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Celebrating the International Year of Periodic Table with chemistry educational games and puzzles

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Abstract:

The purpose of game-based learning is to design learning activities that introduce or explain concepts in more attractive way than in the traditional classroom. Using educational games in the classroom enables innovative and interactive lesson in which the material is seen from a different perspective or point of view. Play is connected to creativity, higher-order thinking, inquiring and problem-solving skills, decision making, collaboration, communication and the development of positive attitudes toward chemistry. The aim of this paper is to emphasize the importance of game-based learning approach in the classroom. Several good practice examples of games and puzzles for chemistry teaching are given to illustrate their applicability in the classroom and to serve as an idea for teachers, thus motivating them to be more creative in finding ways to implement this method and create their own puzzles according to their needs and classroom settings. Motivated by the International Year of the Periodic Table, puzzles are related to the Periodic Table concepts. The presented games can be used to create an escape room classroom, but they can be used independently. We believe that the use of games for educational purposes will be of great benefit to students.

Keywords: chemistry teaching, educational games and puzzles, escape room, innovative approach, International Year of Periodic Table

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Introduction

Game-based learning approach

A game can be defined as an activity or sport usually involving skill, knowledge, or chance, in which fixed rules are followed and try to win against an opponent or to solve a puzzle (<https://www.collinsdictionary.com/dictionary/english/game>). According to Oxford University Press (<https://en.oxforddictionaries.com/definition/game>) games can be considered an activity one engages in either for amusement, fun, a form of competitive activity or sport played according to rules. In fact, games have been defined and redefined many times and these definitions can set limits. Ajaranta (2014) recommends using language-game approach in definitions instead of common core approach. Language-game approach emphasizes the idea of family resemblances i.e. taking into account the elements that are considered important. Namely, different aspects of games can be considered as fundamental, so one can underline their narrativity, rules or playfulness.

The fact that games and game-based learning are concepts that are not easy to define does not mean that play is trivial and unimportant. Undoubtedly, games are more present among young students and represent the main activity in pre-school and early school years. Still, too many people are exposed to games, sometimes even not aware of it. Games can be very beneficial if used properly, having in mind their pedagogical function. They can support the teaching and learning process in schools (Admiraal, Huizenga, Akkerman, & ten Dam, 2011; Burguillo, 2010; Kapp, 2014; Pivec & Dziabenko, 2004), thus helping students to link the knowledge from the game and the one learned at school (Barzilai & Blau, 2014). Play is connected to creativity, higher-order thinking, inquiring and problem-solving skills, decision making, collaboration, communication, etc. Therefore, the benefits of play should be maintained for a long time. As Walt Disney used to say "Every child is born blessed with a vivid imagination. But just as a muscle grows flabby with disuse, so the bright imagination of a child pales in later years if he ceases to exercise it".

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Perhaps one of the most important accomplishments of implementing games in the classroom is the development of positive attitudes toward chemistry since students are fully engaged and mentally involved in the classroom activities, thus having the opportunity both to learn and have fun. Educational games also help students to develop the skills that they will need throughout their lives, thus helping them to grow up in knowledgeable and responsible people (Bernard & Dudek-Różycki, 2019).

In this paper emphasis is put on the celebration of the International Year of Periodic Table (<https://www.iypt2019.org>). Many examples of Periodic Table games are known in literature (Franco-Mariscal, Oliva-Martínez, & Gil, 2015; Martí-Centelles & Rubio-Magnieto, 2014; Sevcik, Hicks, Schultz, & Alexander, 2008). The present paper deals with several games for chemistry (and science) teaching regarding the Periodic Table topic, which is part of the chemistry curriculum both for primary (12–14 years old students) and secondary school (14–18 years old) students.

Pedagogical benefits of using games in the classroom

One of the biggest challenges that teachers face today is to maintain active participation and motivate students to be enthusiastic for learning chemistry. Game-based approach can be a very helpful method to accomplish this goal and to allow students to take ownership of their learning, thus creating a student-centered learning environment. Moreover, teachers get immediate feedback from students and can identify their misconceptions and misunderstandings.

The benefits of educational games as a powerful pedagogical tool in the teaching and learning process has been confirmed in many studies (Antunes, Pacheco, & Giovanela, 2012; Costa, 2007; Franco-Mariscal et al., 2015; Koballa, 1988; Orlik, Gil, & Hernández, 2005) stating that games increase students' motivation, raise interest of the subject and develop positive perceptions toward chemistry. Game-based review lesson promotes much greater student participation and outcome than in the traditional review lesson because students want to win the game (Capps, 2008; Stringfield & Kramer, 2014). It is an exciting way to refresh a student's memory and enables revising important chemical concepts before testing (Campbell & Muzyka, 2002; Russell, 1999).

In North Macedonia, the studies and resources about the usage of game-based method in chemistry teaching (Stojanovska 2017; 2018; Stojanovska & Velevska, 2018) are severally limited. However, some science games can be found (<https://izvorcemk.wordpress.com>), but still they are adopted from English sources or are entirely in English, which often times is a barrier for many teachers and students. Educational games using various software are usually part of the school subject "Working with computers and basis of programming" aimed for 8–10 years students in primary schools (<https://vdocuments.net/priracnik-za-nastavnikot-gcompris-final1.html?h=vdocuments.com.br>). Unfortunately, there are problems with computer equipment and internet access in certain schools, making the usage of these kinds of games hard to implement. Stojanovska and Velevska (2018) offered several good practice examples of "low tech" chemistry games that can be used in the classroom, which were introduced among 9th grade school students (14 years old) and science teachers.

The presented games and puzzles can be used to create an *escape room* classroom or they can be used independently. Games can be modified by teachers to meet their needs and classroom settings. Students can work individually, in pairs or in groups, although working in groups is preferable since it provides teamwork and develops social skills students will need in the future. This way of group work ensures that all students are actively involved and prevents disappointment among the students who would not complete the task within a given time limit if work alone. It also fosters discussion, collaboration and competitiveness among students.

Good practice examples of games and puzzles

An explanation of several games and puzzles is given below. These puzzles are easy to make and no expensive materials or special resources are needed. The teacher can re-group the questions from an old exam test and turn it into an attractive way of gaining knowledge. Many different types of questions can be used: multiple-choice questions, true/false questions, pairing questions, fill-in-the-blank questions, diagrams or pictorial questions etc. For the purpose of this paper, all puzzles were developed by the author. Ideas for creating puzzles can be found on the web (http://www.fakereceipt.us/sales_receipt.php, <https://www.festisite.com/text-layout/maze>, <https://www.keslerscience.com/escape-room-puzzle-ideas-for-the-science-classroom/untitled-design-19>, <https://www.festisite.com/rebus>, <https://snotes.com>). Those puzzles that could be associated to the IYPT theme were used as a starting point to develop own puzzles.

Some of these games were proposed as good practice examples among primary and secondary school chemistry teachers during the seminars held as part of their professional development (Stojanovska, 2019). The purpose was to disseminate the idea of using game-based approach and to be further implemented among students

throughout the country. This idea received a positive response from the teachers, who had great fun during the seminar workshop as well. Even some teachers said that they were so excited by this activity that they immediately after the workshop started creating puzzles for their students. This was a new experience for the teachers, but also for us educators. Namely, in North Macedonia this approach is not well known, although it offers the development not only of cognitive skills but also of the skills that students will need in their further life (such as cooperation, communication, decision-making, etc.). So, this was an additional challenge for us. However, the number of teachers attending this workshop was small compared to the number of chemistry teachers across the country. Furthermore, this approach is not intended exclusively for chemistry teaching, but can be applied to any other subject. Therefore, our commitment is to continue to affirm this approach and to activate as many teachers as possible. We honestly believe that together with teachers we will be able to spread this idea and hopefully to be implemented in schools.

Cool chemistry coffee receipt

The teacher creates fake receipt (Figure 1) in which different type of chemical data are manipulated on a piece of paper. There are clues for students to find among dates, addresses, item purchases, names etc. In this puzzle students should use the name of purchased items which are chemical elements. The aim of this game is students to look for the atomic or the mass number of the elements, the group or the period they belong to, the number of protons, neutrons or electrons etc. In this way, they will revise the most important concepts about the structure of matter, but also offer explanations among themselves and discuss any ambiguity issues related to the topic. They will solve this particular puzzle only if they calculate the number of valence electrons within each of the atoms. The teacher can give students a hint and tell them the number of digits in the code (e.g. whether it is a three-digit or four-digit code).

Figure 1: Cool chemistry coffee receipt.

Municipal chemistry competition

This is an easy puzzle to prepare and involves multiple choice questions. A sample of three questions (Stojanovska, 2018) is given in the Table 1, but the teacher can add as many questions as (s)he likes. The aim of this game is to test the knowledge of students about the structure of matter. This could be done by simple

paper-and-pencil multiple-choice test, but offering additional task which involves some logical thinking not necessarily related to chemistry can increase the excitement among students.

Table 1: Questions for the municipal chemistry competition game.

1. Which of the following pairs do not have the same number of neutrons in the nucleus?
A. K and Ca
B. Na and Mg
C. F and Ne
D. Li and Be
2. Two atoms, X and Y, have a total of 12 protons, 14 neutrons, and 12 electrons. The atomic number of Y is three times larger than that of X. In which group (G) and in which period (P) is the element X?
A. G-1, P-2
B. G-2, P-1
C. G-17, P-2
D. G-2, P-7
3. In the third electron shell of one atom there are twice as low electrons than in the first shell. What is the atomic number of the element?
A. 14
B. 11
C. 9
D. 3

Each answer reveals one digit of the code. To make it more interesting, a multiple-choice grid (Table 2) can be designed and each answer is then compared to a certain symbol, thus each symbol represents one digit. Students are supposed to answer all questions and come up with a code. In this particular case, the correct answers are: 1 – D (which corresponds to the symbol ♥ in the multiple-choice grid and the number 4 in the legend below), 2 – A (which corresponds to the symbol 🎵 in the multiple-choice grid and the number 3 in the legend below) and 3 – B (which corresponds to the symbol @ in the multiple-choice grid and the number 1 in the legend below). So, the code for this puzzle is 431.

Table 2: A multiple-choice grid.

	A	B	C	D
Q1	@	⚙	🎵	♥
Q2	🎵	♥	@	⚙
Q3	♥	@	⚙	🎵

@ = 1.

⚙ = 2.

🎵 = 3.

♥ = 4.

The Queen and the King puzzle

This is a language specific puzzle game because the text is written in Macedonian. Latin letters are used instead of Cyrillic since the text in Figure 2 should be somehow related to certain Periodic Table concepts. This game allows students to practice with the Periodic Table and determine the position of the elements and read their atomic number.

Figure 2: The Queen and the King puzzle.

Two statements are offered to students: “I’m a Queen (KrAlIcA)” and “I Wonder ... What Would I Do Without My King (KrAl)”. Capital letters in the sentences are deliberately used to provoke thinking in different directions and discussion among students. The key to solve this puzzle is to subtract the atomic numbers of elements whose chemical symbols students can recognize in the words Queen (KrAlIcA) and King (KrAl). This puzzle teaches students to carefully read the assignments and to identify the keywords in the texts. Here, the keyword, besides the words *kralica* and *kral*, is *without*, so they could hopefully connect it to the subtraction operation (*KrAlIcA* minus *KrAl* equals *ICa*). When all this is being done, one can obtain the code: 5320 i.e. $A_r(I) = 53$, $A_r(Ca) = 20$. Of course, one can use other combination of words to achieve the similar way of thinking.

Hidden words

The circle in the Figure 3 contains text (four words) which is overlayed into an apparently unreadable puzzle. Still, when the text is rotated at a certain angle, the words become understandable. When printed and rotated, four words can be read: *international*, *year*, *periodic*, *table*. These words give a clear association to one number that can be the code for this puzzle and that is 2019.

Figure 3: Hidden words puzzle – unrotated (a) and rotated (b–e).

This puzzle can be used to test the students’ knowledge about various concepts. Here, words related to the IYPT are used. Other variations of this game can involve different requests, such as: “Determine the first number of the code by answering how many substances are gaseous?”, and four words in the puzzle could be balloon, oxygen, bromine and gold.

Jigsaw puzzle

The teacher can use any theme (s)he wishes or finds it relevant to engage students (<https://www.jigsawplanet.com/?rc=play&pid=1b367f320e20&fbclid=IwAR3LLcr-gKL6QTgqR3hvyNpuOxBv0D6wK8p0ROKrwPksGjCCRYVv88Di7YU>). The images and the number of pieces on the puzzle can be varied. It is important that the image contains a chemistry content to be of educational value; otherwise it would be just a fun activity unrelated to chemistry. The proposed puzzle uses the Periodic Table puzzle pieces to test the students’ knowledge on the position of elements in the Periodic Table and their skillfulness to work in groups and finish in minimum time (see Figure 4). It is expected that students will start arranging the pieces from those elements whose position in the Periodic Table they know, such as sodium, magnesium, chlorine, helium etc. This is exactly the idea of this game – to learn/repeat the position of the elements in the Periodic Table.

Figure 4: Periodic Table Jigsaw puzzle.

IYPT maze

Creating a maze is interesting, easy and cheap activity to involve students. Students can work and compete in groups. The group that finds the way out first is the winner. Additionally, it can involve answering a question (after the question has been found in the maze). These kinds of puzzles should also integrate a chemistry content to be able to serve as educational games. As in the Hidden words puzzle, this one is also aimed to test the knowledge about various concepts in more engagement way.

Try finding the path that says “International Year of Periodic Table” in Figure 5!

Figure 5: IYPT Maze.

Reversed text

When introducing game-based approach in the classroom, the teacher can write a question using reversed text, the text that is rotated 180 degrees. It is suggested to use a font that is difficult to be read. Students will be challenged to read the text and explore ways to succeed faster. Thus, some of them might get the idea to place the text against a mirror or other reflective surface or they can even use the front-facing camera on their mobile phones. Of course, the teacher should leave the students to come up with these (or others) ideas without giving them hints in advance. Thus, in addition to checking out the concepts learned, these kinds of puzzles stimulate students to think creatively and find new solutions to a given problem.

An example of such text is given in Figure 6.

Figure 6: Reversed Text puzzle.

The text on the Figure 6, presented in a more readable manner, is as follows:

Dear students,

Guess the year in which will be the 150th anniversary of the Periodic Table of Chemical Elements and has therefore been proclaimed the International Year of the Periodic Table of Chemical Elements by the United Nations General Assembly and UNESCO.

Rebus

Rebus solving is another well-known game, but students nowadays are not quite familiar with it, especially when used in educational purposes. Thus, it could be an inspiring activity for students and can be used for variety of topics. Students might take some time to figure out how to solve it, but they can have fun and learn at the same time.

The solution for the rebus in Figure 7 is “Periodic Table”. Students should look for the names of the objects in the pictures (or the names can be given below the picture as in this case) and pay attention to different signs in the rebus. The plus sign “+” indicates that the letter(s) after it are added to the word and the minus sign “-” implies that the letter(s) after it are excluded from the word. When students come across the equal sign “=” they need to replace the letters before and after the equal sign.

Figure 7: Rebus.

The longest word

The purpose of this game is students to get familiar with symbols of chemical elements. Their task is to think of as many words as possible using the symbols from the Periodic Table (see Figure 8). The student or the group that will think of the longest word is the winner.

Figure 8: Words composed of chemical symbols during a workshop on chemical education in Croatia.

Conclusions and recommendations for teachers

Introducing games and puzzles in chemistry teaching can provide engagement and entertainment, thus making lessons more enjoyable and interesting for students and enabling students to reflect on the learned material (Capps, 2008; Stringfield & Kramer, 2014). The chemical content is revised in more attractive way, different from what students are used to in the traditional teaching. Through such interactive activities, students develop problem-solving techniques and acquire practical skills in a new, interesting way. They work in groups, but this way enables more active involvement of all students. It is especially beneficial to low-achievers who may fill the gaps in knowledge by discussing with their classmates instead of the teacher they consider to be authority, thus allowing the learning process to happen. This is a formative way of getting insight into students' knowledge. In these educational games there must be chemical content so that it is not just fun, but it is an opportunity for students to learn something or repeat the concepts in a different way.

It can be applied when reviewing concepts from a specific topic, during a diagnostic check of knowledge at the beginning of the year or before introducing a new topic or simply to increase students' interest in chemistry. It is important to note that the goal is to repeat the learned concepts and to expand the knowledge and that students should not be discouraged if a group fails to solve the puzzles to come to the prize.

As mentioned before, some of these games were introduced among primary and secondary school chemistry teachers to disseminate the idea of using game-based approach, hoping that they would make use of these ideas and implement them among their students. Still, the number of teachers was small and no general conclusion about the acceptance and applicability of this approach can be drawn, although the first impression was that teachers were fascinated by the games. More extensive research is needed both among teachers and students to obtain realistic indications of the applicability of this approach.

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