Journal of Research in Science, Mathematics and Technology Education

Volume 1, Issue 2, 113 - 142

ISSN: 2577-6789
http://www.estej.com/

Chemistry Games in the Classroom: A Pilot Study

Marina Stojanovska*

Ss. Cyril and Methodius University, Republic of Macedonia

Blaga Velevska

Aleksandar Makedonski primary school, Republic of Macedonia

Received: April 12, 2108 ▪ Accepted: May 01, 2018

Abstract: In this study a game-based learning approach was introduced among students and teachers. Several chemistry games and a survey method were used as a tool to obtain insight into students' knowledge about ionic bonding, to learn about the students' and teachers' perceptions related to this teaching method and to get insights into the misunderstanding and misconceptions that students might have. Students were tested on the ionic bonding test and both students and teachers anonymously filled in a questionnaire to express their perceptions about the game-based learning approach. Students achievements on the test were satisfactory; the mean score was 11.31 out of 15 (or 75.33 %). Most comments regarding the lesson itself were positive, stating that the lesson was well planned, interesting and very helpful. The usage of games in chemistry classroom was proven to be an excellent way to motivate students, to provide active engagement and discussion among students and to develop skills to solve problems.

Keywords: *Ionic bonding; Game-Based Learning; Chemistry Teaching; Interactive Learning Environment; Cooperative Learning; Educational Games.*

To cite this article: Stojanovska, M., & Velevska, B. (2018). Chemistry Games in the Classroom: A Pilot Study. *Journal of Research in Science, Mathematics and Technology Education*, 1(2), 113-142. doi: 10.31756/jrsmte.121

Introduction

Game-Based Learning

Game-based learning is not easy to define. In many cases it is related to the use of video games as a tool for teaching and learning (Hamari, Shernoff, Rowe, & Coller, 2016; Perrotta, Featherstone, Aston, & Houghton, 2013). However, game types include board, card and video games. Gamification is a much newer concept than game-based learning and it refers to the usage of 'elements' from video-games, which are employed in different settings including education (Pho & Dinscore, 2015). Game-based learning is used to support the learning experience in schools

* **Corresponding author: Marina Stojnovska**
Email: mmonkovic@yahoo.com

(Admiraal, Huizenga, Akkerman, & Dama, 2011; Burguillo, J. C., 2010; Kapp, 2014; Pivec & Dziabenko, 2004) and to help students interlace the knowledge from the game and the one learned at school (Barzilai & Blau, 2014).

Many people have been exposed to game-based techniques even sometimes not being aware of it. This approach has been used in the classroom for several decades. Many successful examples involve environmental chemistry (Pippins et al., 2011), laboratory equipment (Kavak & Yamak, 2016), physical chemistry (Daubenfeld & Zenker, 2015), organic chemistry and biochemistry (Angelin & Ramström, 2010; Costa, 2007; O'Halloran, 2017; Silva & Ribeiro, 2017), periodic table and nomenclature (Franco-Mariscal, Oliva-Martínez, & Gil, 2015; Kavak, 2012; Martí-Centelles & Rubio-Magnieto, 2014; Moreno, Hincapie, & Alzate, 2014; Morris, 2011; Sevcik, Hicks, Schultz, & Alexander, 2008).

Play is sometimes assumed as trivial and unimportant. But, on the contrary, many scientists disagree. Play has a deep biological, evolutionarily important function, which has to do specifically with learning (Prensky, 2000). According to Prensky (2000) it is key to have learners engaged in the process. This engaging powerful force of games stems from their fun side and from the six key structural elements of games: (1) rules; (2) goals and objectives; (3) outcomes and feedback; (4) conflict/competition/challenge/opposition; (5) interaction and (6) representation of story.

Game-based learning offers an excellent way to promote engagement and learning during instruction. The process of learning happens when students are mentally involved in the activity. The idea is for students to have fun and to learn almost as a by-product. Motivation and engagement are considered prerequisites for the successful completion of such activities (Huang & Soman, 2013; Stringfield & Kramer, 2014). The traditional teaching methods only stimulate passive engagement, leading to learning by rote. Boredom or lack of engagement can be considered as the reasons for drop-outs or low performance in education. Nowadays gamification is a popular method to acquire more knowledge and skills (Kim, B., 2013). Huang and Soman (2013) simplify the concept of gamification by a five-step process: understanding the target audience and the context, defining learning objectives, structuring the experience, identifying resources and applying gamification elements.

Game-based approach is based on a constructivist theory of learning (Driver & Oldham, 1986). Students are challenged and engaged and each student is enabled to construct his/her own knowledge. The interaction with other students plays a great role in developing new knowledge and skills. The collaborative or cooperative learning allows participants to exchange information in order to solve a certain problem which can result in a production of new ideas. This approach enables face-to-face interaction, self-confidence and decision making. It also improves information acquisition and retention as well as development of higher-level thinking skills. Working in groups fosters students' self-esteem and lessen the sense of failure. The teacher has an active role in this process – moderates the activity and advises students, unlike the passive function the teacher has in a traditional education. Thus, this approach requires alternative teaching methods. One of the possible ways to engage students and enable learning is the use of games in the classroom. Well-designed educational games stimulate active participation in class and have a positive outcome regarding collaborative and social skills of students. (Costa, 2007; Pivec & Dziabenko, 2004).

Competitiveness is another segment when playing games. The competition can be with another player, non-player or the players themselves (Blunt, 2007). Each group is endeavoring to be a winner. The teacher is crucial at this point and his/her role is to teach students that cooperation is more important than competitiveness and that the gained knowledge is the biggest award.

Game-based learning enables students to find out the necessary information for themselves (Oakman, 2016). It should not come as a surprise that students using games for learning do better in achieving learning objectives than students using traditional instructional methods (Betts, 2015). Games-based learning further provides feedback to the students, increases inquiring and problem-solving skills, promotes critical, creative and higher-order thinking, encourage communication and collaboration and causes the students to be active learners, rather than passive recipients (Kaya, 2010; Kiili, 2005; Prensky, 2000; Sung & Hwang, 2013). This process can be applied to the classroom to support the variety of learning outcomes and to create curious minds. Therefore, educational games represent a powerful pedagogical tool in the teaching and learning process (Antunes, Pacheco, & Giovanela, 2012). These findings are confirmed in many studies conducted using games as a learning tool.

Game-based learning is not just creating games for students to play. Instead, their purpose should be to design learning activities that introduce or explain concepts. The confusion between leisure games and educational games arouse due to the fact that both are used synonymously (de Freitas, 2006). This confusion leads to inappropriate use of leisure games in classroom when they do not follow the principles of good learning design, taking in mind learning goals. Instead, they have being used as a break in the learning. Games should not serve only as an entertaining tool, but instead they should foster active engagement of all students who will tend to master the material while playing and having fun. Games must be well-planned. Always think of their didactic function and implication in the classroom. Play is valuable in the development of creativity and inadvertent learning (Lieberman, 1977). But discussion is the key factor in improving the problem-solving skills, clarification and correction of potential misunderstandings and misconceptions. Therefore, teachers should discuss with the entire class how to arrive at correct answer or correct understanding of the process or a phenomenon. Discussion is an important segment in developing thinking and evaluation and, if appropriately guided, it always produces results.

Games can be applied in chemistry teaching either as a part of a development lesson or a review lesson. It means that they can be used as an introduction to the new material or as a platform to revise the material and practice skills that have been previously taught. Review sessions enable students to reflect on the material, practice and have fun (Kavak, 2012; Stringfield & Kramer, 2014).

Research Problem

This study was conducted in two different settings. In one setting, 9^{th} grade school students aged 14 played the selected games as part of their chemistry review unit on ionic bonding. In the second setting, science teachers attending a workshop were introduced with several games covering different topics. Chemistry games were used as a tool to review what has already been learned and to diagnose any weaknesses and misconceptions students might have. The review lesson was organized in a new interesting way stimulating the thinking and the creativity of students. Except the retention of the material learned, this lesson offered new experiences for students and increased interest of the learned topic. During the workshop, teachers were offered a different approach in realization of the lessons in which review, generalization and systematization of the learned material is needed. It was noted that the aim of these types of lessons is to renew study of the same subject matter and to recall what has been previously discussed. Also, it was emphasized that it is important to view the material from a different perspective or point of view. Therefore, usage of chemistry games in the classroom can be considered as a part of interactive lessons that provide practice in acquiring knowledge and skills.

The chemistry games offered in this study can be used in science lessons among younger students in science or in chemistry courses in primary and even in secondary schools. All materials for game preparation were handcrafted and easily available. This is especially important in not very well-equipped schools where teachers have no access to funds and resources needed for the teaching process. In this manner one more thing is important to note, having in mind the drawbacks of some games (Koether, 2003), such as involvement of a limited number of students, requirement of major explanations of the game rules and computer assistance or taking too much time to prepare. The advantage of games used in this study is the fact that the explanation and preparation time was minimal and no computer requirement was necessary. Our expectation is that the games tested would be valued positively by students and teachers, thus leading to positive perceptions about their usage in the teaching and learning process.

As another important aspect in our investigation, we plan to focus on informal discussions with students and teachers to provide deeper insight into the teaching process and to plan our future research relevant to practice by identification of real problems that concern both students and teachers. In particular, we are most interested in the attitude of teachers and students towards this method and the views of teachers about its applicability in the classroom.

In Macedonia, there are no investigations about the usage of game-based learning method in chemistry classes. Therefore, it is crucial to explore the possibilities to introduce this method as well as the interest of teachers to apply it in their lessons. In this paper, we offer several good practice examples of chemistry games that can be used in the classroom only as a starting point. We hope to design more games that will find its place in the teaching process and to find ways to disseminate this idea to the teachers in Macedonia.

Having in mind all of the above mentioned, we formulated three research questions:

(1) What are the misunderstandings and misconceptions of students about ionic bonding?

(2) What are the perceptions of students related to the game-based learning method?

(3) What are the perceptions of teachers related to the game-based learning method and their opinions about the further application of this method in chemistry classes?

Method

Participants

The study was conducted in two different settings. In one setting, 45 9th grade students (≈ 14 years old) from two classes in one school in Macedonia in the 2017/18 school year played three games related to the ionic bonding. The data obtained were used for research purposes only and all information was kept confidential. Therefore, each student was assigned a code (S1, S2 etc.) when analyzing the data. The study was conducted after the approval of the chemistry teacher and the school management. The results of the test did not affect students' grades.

In the second setting, science and chemistry teachers who choose to participate in a workshop (Friends of Education, 2018) were participants and game players. Active participation in the workshop was limited to 20 teachers; all others were observers.

Instruments

Instruments for students.

Before the lesson, students were given a short test on ionic bonding to assess their general knowledge on this topic. The test given to students before the lesson consisted of four questions:

1. The first one was a fill-in-the-blank type question and asked students to recognize whether an atom (atom of sodium/chlorine) would gain or lose electron/s (and how many) to form a sodium chloride entity. This question was worth 4 points.
2. The second one was also a fill-in-the-blank type question and tested students' knowledge on the role of valence electrons in ionic bond formation on the example of magnesium fluoride. This question was worth 2 points.
3. The third question asked students to determine the correctness of the three given statements; they could get maximum 3 points for this.
4. The fourth one required using a scheme to represent the ionic bond formation in magnesium fluoride, paying attention to valence electrons and their transfer from one atom to another, and to the ions formed. Maximum score for this question was 6.

One week after the lesson, students took a survey as a part of a post-class assessment. They were asked to fill in a questionnaire (anonymously) in which they expressed their feelings and opinions regarding the game-based teaching method used previously.

Instruments for teachers.

Teachers were given very similar questionnaire to the one given to students, except some statements were rephrased to represent teacher's points of view. The questionnaire was filled in anonymously to enable teachers to present their opinions more freely. A total of 16 teachers completed the survey. Details are given in the Result and discussion section.

The questionnaires used in this study were Likert-type scales of 9 statements on which students/teachers were supposed to agree or disagree. The questionnaires included a brief introduction in which explanation of the way it should be completed was given. The measuring scale ranged from 1 (strongly disagree) to 4 (strongly agree).

Research Design

Research goals.

The main research goals of this study were:

- to learn about the perceptions of both students and teachers related to the game-based learning method and to inspect their views and opinions about further applications of this method in chemistry classes, and
- to increase the awareness among students about possible misunderstandings and misconceptions they might have about ionic bonding.

The chemistry games.

The games that we have focused on in this study were aimed to serve to several learning objectives in two school subjects: Science (for 9−11 years old students) and Chemistry (for 13−14 years old students). The learning objectives important for games are briefly summarized in the following table.

Table 1.

Learning Objectives in Science and Chemistry Courses

Learning objectives	
Science	**Chemistry**
Students know that matter can be in a solid, liquid or gaseous state.	Students describe everyday materials and their physical properties.
Students distinguish between soluble and insoluble substances.	Students know the chemical symbols of the first 20 elements using the periodic table, as well as some other known elements including iron, zinc, copper, lead, silver, gold, and iodine.
Students know that when liquid evaporate from the solution, a solid remains in the vessel (providing there is a solid dissolved).	
Students distinguish between reversible and irreversible changes.	Students describe the formation of ions (cations and anions) by losing or gaining of electrons from atoms.
Students make assumptions using scientific knowledge and understanding.	Students make predictions using scientific knowledge and understanding.
Students perform relevant observations and comparisons in a variety of contexts.	Students discuss the results using scientific knowledge and share them with others.

As already mentioned, chemistry games used in this study are easy to prepare and require an old deck of cards or a cardboard/scraperboard pieces, marbles, dice and plastic cups. Games played in the classroom were: Ion Poker, Marble Madness and Make me a Formula, and in the workshop: Ion Poker, Surprise Box, Domino and The Longest Word. The set-up for some games is given at Figure 1. We have chosen only three games for students to play in the classroom as a part of their review lesson. These games were related to the topic learnt in school about ionic bonding and were the most suitable to use at this point of time. Also, not all proposed games were played in the workshop because the time restriction. One session (one workshop) was limited to 45 minutes and it was not possible to cover all planned activities.

The research aimed to inspect students' perceptions consisted of three parts: (1) simple test, (2) introducing and playing the games in the classroom and (3) informal discussions. The research that involved teachers comprised two parts: (1) introducing and playing the games in the workshop and (2) informal discussions.

One week before the realization of the review lesson about ionic bonding, students were given a simple four-question test. Details about the test are given in the Instrument section. The reason for giving such short test was to evocate students for the forthcoming class and to get fast insight into their previous knowledge regarding ionic bonding. The teacher (or the researcher or PhD student), just by looking superficially into the answers, can notice the parts in the test in which students had most difficulties in giving the right answer. Furthermore, he or she can immediately and adequately intervene by providing the suitable explanations where necessary, thus making the connection between the learned material and the games stronger. The authors made an effort to realize all activities in shorter amount of time due to the fact that teachers must strictly follow the national curriculum and therefore do not allow many classes to be hold by others (researchers or master and PhD students).

During the realization of the lesson the chemistry teacher, the researcher and three assistants were present. The assistants were chemistry students in their final year of study (pre-service teachers). They were familiar with the games and helped in organization before and during the class. Students from two classes from one school in Macedonia participated in the research: 21 students were present in one class and 24 in the other. They were divided into groups of four or five for playing the first game – the Ion Poker game. Next, the second game (Marble Madness) required two groups of students to merge into one, thus making groups that consisted of 8 to 10 students in each one. Each group was given three index cards: on the first one “easy” formula was written (e.g. NaCl or KF) and then more “complicated” ones (e.g. MgF_2 or Na_2O in the second index card and Al_2O_3 or Mg_3N_2 in the third one). The last game was called Make me a Formula and required specially designed dice. There is no defined time to finish each game, but the first two games lasted approximately 15 minutes including the time for pre- and post-explanations. It is important that the teacher explains the game rules before starting the game and to offer additional explanations afterwards to make sure that all students understood the concepts which the game is based on. The teacher can vary the cards given at the beginning to each student in the Ion Poker game or the number of index cards given to each group in the Marble Madness game according to his/her needs and the time allowed. The Make me a Formula game was deliberately left last because in this game the time is not the limiting factor, meaning it can be played for 5 or for 20 minutes. Moreover, students are not grouped, but the game is played with all students. Namely, one student rolls the dice in front of the class and writes the corresponding formula on the board. Thus, we thought it would be wise to leave this game as last and enable students to play the game until the end of the lesson.

Games played in the workshop were Surprise Box, Ion Poker, Domino and The Longest Word. Participants were organized in groups of five and were supposed to think of a name for their group. The workshop was designed as some kind of competition among groups. Each group received points for each game according to the accomplishments of the participants. The first game, Surprise Box, was played among the members within the group. For the other three games new arrangements were made so that new groups were formed. These new groups were formed by one participant from each initial group. At the end, all points were summarized and the winner group was announced. Also, small rewards were prepared for each participant in the winner group.

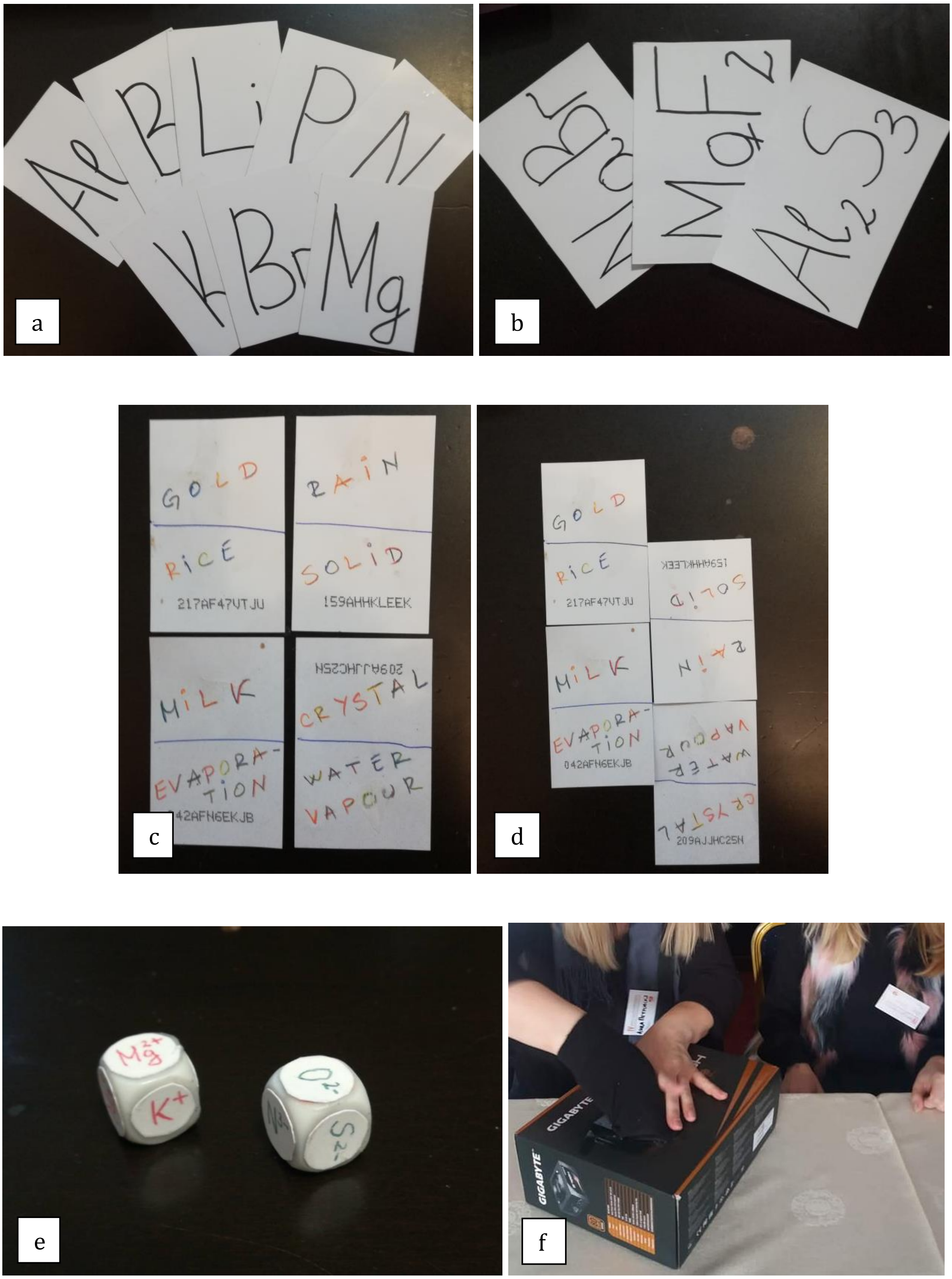

Figure 1. Game set-ups for Ion Poker (a), Marble Madness (b), Domino, at the beginning (c), Domino, during the play (d), Make me a Formula (e), Surprise Box (f)

(1) **Ion poker**. Ion poker game was played among students in the classroom and among teachers in the workshop. This game helps students to learn how to determine the number of electrons an atom will gain or lose when forming an ion (Howe, Krone, Reiter, & Verby, 2005). Materials needed for this game are handmade index cards with symbols of elements written on them (e.g. P, Li, Mg, O, …) and marbles which represented electrons.

Participants work in groups of four or five. Each participant has 10 marbles placed in a plastic cup. One person is a dealer and each participant within the group receives 5 cards. The dealer begins the play by setting down a card of his/her choice. After finding the symbol of the element on the periodic table chart, he/she determines the number of electrons that the atom loses or gains when forming an ion. Then, the dealer chooses one player from the group. If the atom loses electrons, the appropriate number of marbles must be taken from the dealer. If the atom gains electrons, the appropriate number of marbles must be given to the dealer. The winner is the person who has the greatest number of marbles after all cards have been played.

(2) **Marble madness**. Marble Madness game (Howe et al., 2005) was played among students in the classroom. Students were divided into groups of 8 or 10. Half of the students received one plastic cup with four marbles. The other half of the students got only an empty cup and no marbles. As in Ion Poker game, the marbles represented electrons. Students were divided into marble givers (i.e. electron givers, electron donors) and marble acceptors (electron acceptors). Based on their understanding the principle of ionic bonding, students were supposed to transfer marbles to one another.

Each group was given a handmade index card with a chemical formula written on it (e.g. MgF_2). The task of students was to rearrange themselves to fulfill the electron(s) transfer. In this case (MgF_2), if a group is consisted of 8 members – 4 givers and 4 acceptors, two givers (Mg^{2+} cations) and four acceptors (F^- anions) are needed to complete the task. It is advisable to start with “easy” chemical formulae (such as NaCl and KF) that require only one electron to be transferred and then move on to more complicated situations.

(3) **Surprise box**. The aim of this game is to introduce materials and their properties to students. The teacher/instructor prepares the box before the class activity by making a round section on one side of the box. A piece of sock, shirt sleeve or pants legs can be attached to the hole. Unknown object is put inside the box. The student should guess the object inside, which material it is made of and try to describe it by using its properties such as texture, size, hardness etc. The skill students need to learn is to observe indirectly, use other senses other than their eyes and to understand what a property is.

(4) **Domino**. Domino is a famous game that is played with domino tiles. For the purpose of this study “dominoes” were made out of album thumbnails background and were related to the states of matter. Two terms or phrases were written on each thumbnail background. Before the game begins, the players have to determine who makes the first move. It is usually done by an agreement or by rolling a dice. Next tiles are placed so that only the "open" ends of a layout are open for play. If a player cannot make a move, he/she takes one tile from the deck. The first player to play all his/her tiles is the winner.

(5) **The longest word**. Within this game student learn about symbols of chemical elements. The goal is to think of as many words as possible in a certain amount of time using the symbols from the periodic table. The winner is the group that has the longest word. Also, some credit could be given to the one that “invented” most of the words, irrespectively of their length.

(6) **Make me a formula**. This is a game about chemical nomenclature of ionic compounds (mainly salts). One student rolls two dice: one with cations written on every sides and another with anions. The student should write a chemical formula of the selected cation-anion pair.

Data analysis.

The main focus of this study was to collect the opinions and perceptions of students and teachers concerning the use of educational games in the chemistry/science class. Additionally, simple test was introduced to students to evocate and diagnose students' previous knowledge and to get insights into students' misunderstandings and misconceptions regarding ionic bonding. The information obtained by the informal discussions with both students and teachers was considered beneficial for further in-depth research in this field and represents a valuable tool for improving particular aspects of the study.

A simple test was used to get immediate diagnose of students' knowledge about ionic bonding. The main focus of this study was to acquaint students with the chemistry games and to measure their attitude towards game-based learning approach, not to test their knowledge. The simple test was designed to superficially assess the students' knowledge needed as a base for realization of the learning objectives for the particular class. It was requested by the school management to use not too many classes for the research, so it was not possible in this short amount of time to test both students' knowledge of this topic and their perceptions about chemistry games. As this was only a pilot study, all information obtained together with the shortcomings and flaws in the study would be used in deeper and wide-ranging research.

Still, to answer the first research question, the mean scores and standard deviations of each question were calculated and further qualitative analysis of explanatory questions was performed to provide an information on potential misunderstandings of students.

Likert-type scale questionnaire was used to identify and collect information regarding the perceptions of students and teachers. The Likert-type scale technique is commonly used in social studies for the assessment of attitudes (Croasmun & Ostrom, 2011). The prepared test questions and questionnaire statements were examined by one university teacher and one school teacher and necessary adjustments were made before administration. Cronbach's alpha coefficient (Namdeo &

Rout, 2016; Wessa, 2018) was calculated as a measure of internal consistency reliability of the instrument.

The questionnaire was tested on a pilot group of 45 school students and 20 science and chemistry teachers. The starting idea was to explore the perceptions of small group of teachers and students and to extend to a broader population. As a matter of fact, the small sample size is one of the limitations of this study.

Specifically, a 9-item perception scale was used. The statements were slightly different for teachers and for students and reflected students'/teachers' perceptions about the effectiveness of the educational games, the simplicity of the game rules, game mechanism to enable involvement of all students etc. The questionnaire contained items in a 4-point Likert-scale and the ratings ranged from 1 (strongly disagree) to 4 (strongly agree). Comments of students and teachers were valuable in understanding difficulties and addressing possible misconceptions they might have regarding discussed topics.

The statements used in the questionnaire were:

Statements from the students' questionnaire	Statements from the teachers' questionnaire
The lesson involving educational games was interesting.	The workshop involving educational games was interesting.
I have learned something new.	I have learned a new method of teaching.
Educational games helped me to broaden my knowledge regarding ionic bonding.	Educational games can help students to broaden their knowledge regarding ionic bonding.
The activities were adequate to the learned material.	The activities were adequate to the curriculum.
The indicated examples were adequate to the learned material.	The indicated examples were adequate to the curriculum.
The activities involving educational games helped me clarify misunderstandings about ionic bond.	The activities involving educational games can help students to clarify their misunderstandings about ionic bond.
The time frame was maintained.	The time frame was maintained.
I could understand the teacher's explanations easily and clearly and the instructions/rules were easy to follow.	I could understand the presenter's explanations easily and clearly and the instructions/rules were easy to follow.
All group members were active.	All group members were active.

Results and Discussion

Before the lesson, students' knowledge on ionic bonding was tested using a simple test. The test consisted of four questions: the first two were fill-in-the-blank type questions; the third one asked them to determine the correctness of the given statements and the fourth one required more complex knowledge of using a scheme to represent the ionic bond formation in magnesium fluoride.

To answer the first research question, the analysis of the test results was made by calculating the mean scores and standard deviations of each question (Table 2). Cronbach's alpha for this pilot study was quite low (0.463) and this test cannot be a reliable measure of students' knowledge, but only to provide an immediate feedback and information of their misunderstandings. Furthermore, a deeper analysis of the responses was conducted, especially to the fourth question. Misunderstandings revealed by this analysis are reported below. The maximum test score was 15. A total of 45 students took the test. The achievements of students are given in Figure 2.

Table 2**.**
Average test scores

Test item	**Q1**	**Q2**	**Q3**	**Q4**	**Total**
Mean score	3.42	1.89	2.78	3.22	11.31
SD	0.89	0.32	0.60	1.98	2.86

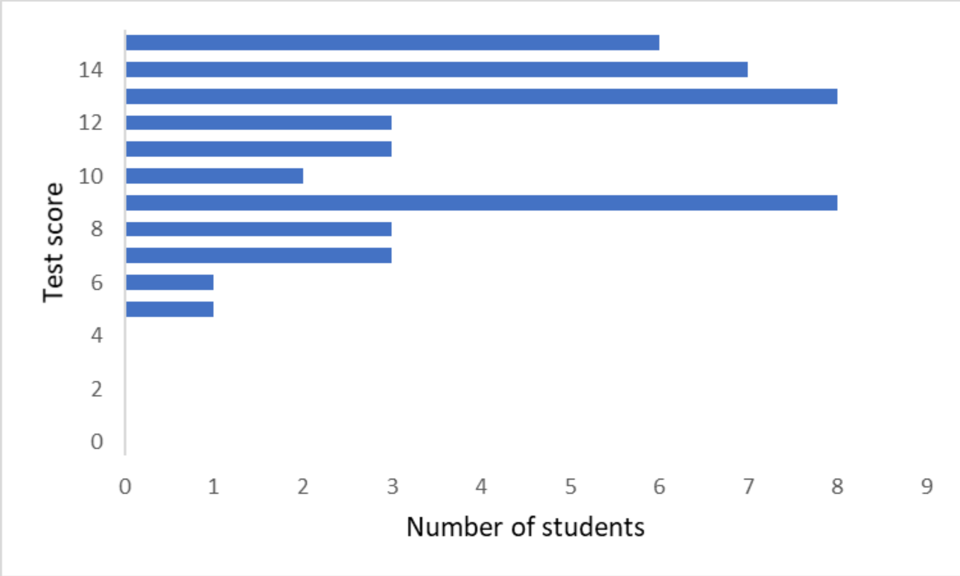

*Figure 2***.** Students' scores on the test

Most students had a well-established knowledge regarding the ionic bonding. Nearly half of the students (46.7 %) had high score on the test (between 13 and 15 points) and approximately two thirds of students (64.4 %) had 10 or more points. The previously acquired knowledge helped students to follow the intervention game-based program and to work according to the game rules.

Most mistakes were recorded in the fourth question, which was the most complex one. Six out of 45 students gave fully correct answer (an example is given in Fig. 3). Most students wrote electronic arrangement although it was not necessary. It was noticed that students were facing some difficulties when explaining the ionic bond formation using a scheme. Some of the most common misunderstandings were:

- writing an incorrect charge script (ionic charge) neglecting the IUPAC notation for ionic charges (Jensen, 2012), such as "+2" or "++" instead of "2+" (Fig. 4)
- arrows pointing the "path" of the electron not clearly marked (Fig. 4 right and Fig. 5 left) or no arrows at all (Fig. 4 left and Fig. 5 right)

- not paying attention to the number of atoms needed for bonding to happen (Fig. 4 left and Fig. 5 right) or to the number of ions formed (Fig. 5 left)

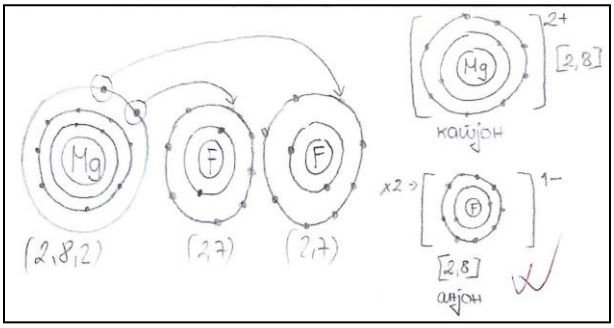

Figure 3. Answer to question 4 – a good example

Figure 4. Answers to question 4 – incorrect charge script (ionic charge)

Figure 5. Answers to question 4 – misunderstandings

Survey for students. Students were given a questionnaire to state their attitude about the teaching method (research question 2). There were 9 statements on this questionnaire and four options to choose from: 1 – strongly disagree, 2 – disagree, 3 – agree and 4 – strongly agree. All 45 students responded to the questionnaire. The mean scores ranked from 3.24 to 3.73. The data obtained are summarized in the following table.

Table 3.

Results of students' survey

Statement	Mean score	SD
The lesson involving educational games was interesting.	3.67	0.56
I have learned something new.	3.24	0.77
Educational games helped me to broaden my knowledge regarding ionic bonding.	3.38	0.81
The activities were adequate to the learned material.	3.73	0.45
The indicated examples were adequate to the learned material.	3.64	0.57
The activities involving educational games helped me clarify misunderstandings about ionic bond.	3.36	0.86
The time frame was maintained.	3.49	0.66
I could understand the teacher's explanations easily and clearly and the instructions/rules were easy to follow.	3.24	0.88
All group members were active.	3.53	0.79

In addition, students had an opportunity to comment the realization of the lesson and to note their learning difficulties on ionic bonding topic. Most students did not write any comments, and some of them claimed that they had no difficulties at all. Only one student gave more extended comment:

S26: *"I used to have problems about the valences and about gaining and losing electrons, but these games and activities helped me overcome those misunderstanding and get more solid knowledge about this topic."*

Most comments regarding the lesson itself were positive, stating that the lesson was well planned, interesting and very helpful. One student had an interesting comment:

S27: *"I think that the teacher needed to explain more about ionic bonding instead of waiting for us to give the answers."*

The student thought that the teacher should not wait for their responses and should give the correct answer right away although it was a review lesson. This can indicate the way students are thought in our schools. In the authors' opinion, students should be given enough time to think about certain problem and encourage students to come up with the solution by themselves rather than providing them ready-made (instant) answers.

Survey for teachers.

This questionnaire consisted of 9 statements as well which were very similar to those of students. They were adopted to measure the teachers' points of view regarding the game-based method proposed during the workshop (research question 3). Teachers' standpoints are summarized in Table 4.

Teachers did not comment much on the questionnaires. Some of them expressed their satisfaction of the workshop stating it was very useful to them. They found the indicated games to be a useful tool to make the learning process more enjoyable as they were enjoying the workshop themselves. In one comment it was noted that students often have difficulties in determining valences of certain atoms.

Table 4.

Results of teachers' survey

Statement	Mean score	SD
The workshop involving educational games was interesting.	3.88	0.34
I have learned a new method of teaching.	3.75	0.45
Educational games can help students to broaden their knowledge regarding ionic bonding.	3.81	0.40
The activities were adequate to the curriculum.	3.81	0.40
The indicated examples were adequate to the curriculum.	3.81	0.40
The activities involving educational games can help students clarify their misunderstandings about ionic bond.	3.75	0.45
The time frame was maintained.	3.75	0.45
I could understand the presenter's explanations easily and clearly and the instructions/rules were easy to follow.	3.88	0.34
All group members were active.	3.88	0.34

Cronbach's alpha and related statistics for internal consistency reliability are shown in Tables 5 and 6. As can be seen, the Cronbach's alpha values obtained for the students' and teachers' questionnaires are 0.9088 and 0.9321, respectively. This is an indicator that both questionnaires showed an excellent internal consistency and can be considered as reliable instruments for measuring the perceptions of students and teachers.

Table 5.

Cronbach's alpha and related statistics for students' questionnaire

Items	Cronbach's Alpha	Std. Alpha	G6 (scm)	Average R
All items	0.9088	0.9081	0.9204	0.5235
1 excluded	0.9072	0.9057	0.9169	0.5457
2 excluded	0.8881	0.8889	0.8980	0.5001
3 excluded	0.8906	0.8921	0.9013	0.5082
4 excluded	0.9090	0.9072	0.9151	0.5499
5 excluded	0.9055	0.9039	0.9120	0.5404
6 excluded	0.8944	0.8942	0.9055	0.5138
7 excluded	0.9008	0.9011	0.9142	0.5324
8 excluded	0.8881	0.8877	0.9020	0.4969
9 excluded	0.8986	0.8980	0.9064	0.5238

Table 6.

Cronbach's alpha and related statistics for teachers' questionnaire

Items	Cronbach's Alpha	Std. Alpha	G6 (scm)	Average R
All items	0.9321	0.9313	0.9807	0.6011
1 excluded	0.9442	0.9449	0.9872	0.6820
2 excluded	0.9152	0.9157	0.9750	0.5760
3 excluded	0.9185	0.9185	0.9737	0.5848
4 excluded	0.9327	0.9326	0.9745	0.6335
5 excluded	0.9185	0.9172	0.9736	0.5808
6 excluded	0.9295	0.9279	0.9833	0.6167
7 excluded	0.9152	0.9157	0.9750	0.5760
8 excluded	0.9198	0.9171	1.0000	0.5802
9 excluded	0.9198	0.9171	1.0000	0.5802

Conclusion

The survey results showed that the teaching unit of ionic bonding involving the use of game-based approach (educational games) led to the development of positive attitudes toward chemistry and resulted in student learning both at cognitive and affective level. The lowest score on the students' survey was regarding the teacher's explanations and following the rules. This was not the case with teachers attending the workshop. It seems that the games instructions were not so easy to be understood by students, thus some improvements seem to be necessary in this respect in the future.

The educational games used in this pilot study, overall, successfully engaged and motivated both students and teachers. These games provided an enjoyable way for students/teachers to work together in groups and enabled learning to arise from playing the game. These findings are in agreement with other studies which have confirmed that educational games improve students' motivation, raise interest of the subject and contribute to the development of positive perceptions toward science (Costa, 2007; Franco-Mariscal, Oliva-Martínez, & Gil, 2015; Koballa, 1988). Orlik et al. (2005) found the use of games to be one of the most important approaches in the teaching of chemistry.

Another benefit of using game-based approach is the immediate feedback from students and identification of their misconceptions. Game-based learning is especially useful in cases where it is difficult to make connections with the real life (for example, when teaching more abstract concepts such as chemical bonding).

Furthermore, providing students with an opportunity to design their own deck of cards can be used as a classroom activity before playing the games. This way, students will be even more involved and focused on the activities. It is a nice example how "low tech" games can be used as a powerful tool in education at almost no cost and only a little effort. It could come as a surprise that students will still be in the classroom playing after an entire 40-minute period.

The study has some limitations to keep in mind. Although the minimum number of subjects for experimental research is 30 (Hoque et al., 2011), still larger sample size involving students from various schools might be needed to obtain more reliable results. Furthermore, there are no information on how this lesson influences students' further educational development and achievement in chemistry. To get even deeper insights into students' knowledge and beliefs, we plan interviews with students who participated in this study. Also, in our future studies we will attempt to verify the findings through students' performances involving written tests.

It seems important to disseminate the idea of using educational games in the class. Not many teachers in Macedonia are familiar with this approach. The authors are challenged to encounter the idea of using games for educational purposes and to try to include as many teachers as possible from different background. Furthermore, we attempt to develop more educational games together with science teachers from primary and secondary schools in Macedonia and to popularize these good practice examples among teachers and their students. The experience that teachers have from their teaching practice is very much appreciated and could be a valuable source of information. Continuing these activities can lead to development of new knowledge and deepening the existing one.

At the end, applying game-based approach indeed improves both the teaching and learning process. However, it does not mean that it should be a replacement for the face-to-face instruction. The firm relationship between the teacher and students is still crucial in the process of education.

Acknowledgements

We would like to thank Prof. Vladimir M. Petruševski for the suggestions made and to all students and teachers who participated and contributed to this investigation.

References

Admiraal, W., Huizenga, J., Akkerman, S., & Dama, G. (2011). The concept of flow in collaborative game-based learning. *Computers in Human Behaviour, 27*(3), 1185−1194. doi: 10.1016/j.chb.2010.12.013

Angelin, M., & Ramström, O. (2010). Where's Ester? A game that seeks the structures hiding behind the trivial names. *Journal of Chemical Education, 87*(4), 406−407. doi: 10.1021/ed800129r

Antunes, M., Pacheco, M. A. R., & Giovanela, M. (2012). Design and implementation of an educational game for teaching chemistry in higher education. *Journal of Chemical Education, 89*(4), 517−521. doi: 10.1021/ed2003077

Barzilai, S., & Blau, I. (2014). Scaffolding game-based learning: Impact on learning achievements, perceived learning, and game experiences. *Computers & Education, 70*(1), 65−79. doi: 10.1016/j.compedu.2013.08.003

Betts, B. (2015). Game-based learning. In_R. Hubbard (Ed.), *The Really Useful eLearning Instruction Manual: Your toolkit for putting eLearning into practice* (pp. 175−194). John Wiley & Sons Ltd. doi:10.1002/9781118375860v

Blunt, R. (2007). Does game-based learning work? Results from three recent studies. Retrieved from https://www.reality-xp.com/professional/files/GameBasedLearningStudies.pdf

Burguillo, J. C. (2010). Using game-theory and competition-based learning to stimulate student motivation and performance. *Computers & Education, 55*(2), 566−575. doi: 10.1016/ j.compedu.2010.02.018

Costa, M. J. (2007). Carbohydeck: A card game to teach the stereochemistry of carbohydrates. *Journal of Chemical Education, 84*(6), 977–978. doi: 10.1021/ed084p977

Croasmun, J. T., &Ostrom, L. (2011). Using Likert-type scales in the social sciences. *Journal of Adult Education, 40*(1), 19−22.

Daubenfeld, T., & Zenker, D. (2015). A Game-based approach to an entire physical chemistry. *Journal of Chemical Education, 92*(2), 269−277. doi: 10.1021/ed5001697

de Freitas, S. (2006). Learning in Immersive worlds: A review of game-based learning. Retrieved from http://researchrepository.murdoch.edu.au/id/eprint/35774/1/gamingreport_v3.pdf

Driver, R., & Oldham, V. (1986). A constructivist approach to curriculum development in science. *Studies in Science Education*, *13*(1), 105−122. doi: 10.1080/03057268608559933

Franco-Mariscal, A. J., Oliva-Martínez, J. M., & Gil, M. L. A. (2015). Students' perceptions about the use of educational games as a tool for teaching the periodic table of elements at the high school level. *Journal of Chemical Education, 92*(2), 278−285. doi: 10.1021/ed4003578

Friends of Education (2018, March 31−April 1). Fourth Educonference for Teachers and IT Experts, Struga, Republic of Macedonia

Hamari, J., Shernoff, D. J., Rowe, E., & Coller, B. (2016). Chalenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Computers in Human Behavior, 54*(1), 170−179. doi: 10.1016/j.chb.2015.07.045

Hoque, K. E., Alam, G. M., Ariff, M. R. B. M., Mishra, P. K., & Rabby, T. G. (2011). Site-based management: Impact of leader's roles on institutional improvement. *African Journal of Business Management, 5*, 3623–3629.

Howe, M., Krone, B., Reiter, S., & Verby, D. (2005). Chemistry as fun and games. Retrieved from http://nobel.scas.bcit.ca/chemed2005/tradingPost/TUPM_S2_4_15ChemFunGames.pdf

Huang, W. H., & Soman, D. (2013). *A practitioner's guide to gamification of education*. Toronto, ON: Rotman School of Management University of Toronto.

Jensen, W. B. (2012). The proper writing of ionic charges**.** *Journal of Chemical Education, 89*(8), 1084–1085. doi: 10.1021/ed2001335

Kapp, K. (2014, March). Gamification: Separating fact from fiction. *Chief Learning Officer*. Retrieved from http://ww.w.cedma-europe.org/newsletter%20articles/Clomedia/Gamification%20-%20Separating%20Fact%20from%20Fiction%20(Mar%2014).pdf

Kavak, N. (2012). ChemOkey: A game to reinforce nomenclature. *Journal of Chemical Education, 89*(8), 1047−1049. doi: dx.doi.org/10.1021/ed3000556

Kavak, N., & Yamak, H. (2016). Picture chem: Playing a game to identify laboratory equipment items and describe their use. *Journal of Chemical Education, 93*(7), 1253–1255. doi: 10.1021/acs.jchemed.5b00857

Kaya, T. (2010, November 7). A ‘Stealth assessment’ turns to video games to measure thinking skills. *The Chronicle of higher education*. Retrieved from https://www.chronicle.com/article/A-Stealth-Assessment-Turns/125276

Kiili, K. (2005). Digital game-based learning: Towards an experiential gaming model. *Internet and Higher Education, 8*(1), 13–24. doi:10.1016/j.iheduc.2004.12.001

Kim, B. (2013, May 21). Keeping Up With... Gamification, American Library Association. Retrieved from http://www.ala.org/acrl/publications/keeping_up_with/gamification

Koballa, T. R. (1988). Attitude and related concepts in science education. *Science Education, 72*(2), 115−126. doi: 10.1002/sce.3730720202

Koether, M. (2003). The name game: Learning the connectivity between the concepts. *Journal of Chemical Education, 80*(4), 421−422. doi: 10.1021/ed080p421

Lieberman, J. N. (1977). *Playfulness: Its relationship to imagination and creativity*. New York: Academic Press.

Martí-Centelles, V., &Rubio-Magnieto, J. (2014). ChemMend: A card game to introduce and explore the periodic table while engaging students’ interest. *Journal of Chemical Education, 91*(6), 868−871. doi: 10.1021/ed300733w

Moreno, L. F., Hincapie ́, G., & Alzate, M. V. (2014). Cheminoes: A didactic game to learn chemical relationships between valence, atomic number, and symbol. *Journal of Chemical Education, 91*(6), 872−875. doi: 10.1021/ed4008183

Morris, T. M. (2011). Go chemistry: A card game to help students learn chemical formulas. *Journal of Chemical Education, 88*(10), 1397–1399. doi: 10.1021/ed100661c

Namdeo, S. K., & Rout, S. D. (2016). Calculating and interpreting Cronbach’s alpha using Rosenberg assessment scale on paediatrician’s attitude and perception on self esteem. *International Journal of Community Medicine and Public Health 3*(6), 1371−1374. doi: http:dx.doi.org/10.18203/2394-6040.ijcmph20161448

O’Halloran, K. P. (2017). Teaching classes of organic compounds with a sticky note on forehead game. *Journal of Chemical Education, 94*(12), 1929−1932. doi: 10.1021/acs.jchemed.7b00165

Oakman, H. (2016 June 7). The rise of game-based learning. Retrieved from https://edtechnology.co.uk/Article/the-rise-of-game-based-learning

Orlik, Y., Gil, E., & Hernández, L. C. (2005). The game “young scientists “ as active science educational tool for extra-curricular work in the school. *Natural Science Education, 3*(14), 47−50. Retrieved from http://oaji.net/articles/2014/514-1393349254.pdf

Perrotta, C., Featherstone, G., Aston, H., & Houghton, E. (2013). *Game-based learning: Latest evidence and future directions* (NFER Research Programme: Innovation in Education). Slough: NFER.

Pho, A., & Dinscore, A. (2015, Spring). *Game-based learning: Tips and Trends*. Retrieved from http://acrl.ala.org/IS/wp-content/uploads/2014/05/spring2015.pdf

Pippins, T., Anderson, C. M., Poindexter, E. F., Sultemeier, S. W., & Schultz, L. D. (2011). Element cycles: An environmental chemistry board game. *Journal of Chemical Education, 88*(8), 1112–1115. doi: 10.1021/ed100576a

Pivec, M., & Dziabenko, O. (2004). Game-based learning in universities and lifelong learning: “UniGame: social skills and knowlwdgw training” game concept. *Journal of Universal*

Computer Science, 10(1), 14−26. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.100.1704&rep=rep1&type=pdf

Prensky, M. (2000). *Digital game-based learning*. New York: McGraw-Hill.

Sevcik, S. R., Hicks, O., Schultz, L. D., & Alexander, S. V. (2008). Elements— A card game of chemical names and symbols. *Journal of Chemical Education, 85*(4), 514−515. doi: 10.1021/ed085p514

Silva, D. M., & Ribeiro, C. M. R. (2017). Analogue three-dimensional memory game for teaching reflection, symmetry, and chirality to high school students. *Journal of Chemical Education, 94*(9), 1272−1275. doi: 10.1021/acs.jchemed.7b00219

Stringfield, T. W., & Kramer, E. F. (2014). Benefits of a game-based review module in chemistry courses for nonmajors. *Journal of Chemical Education, 91*(1), 56−58. doi: 10.1021/ed300678f

Sung, H., & Hwang, G. (2013). A collaborative game-based learning approach to improving students' learning performance in science courses. *Computers & Education, 63*, 43−51. doi: 10.1016/j.compedu.2012.11.019

Wessa, P. (2018). Free Statistics Software, Office for Research Development and Education, version 1.2.1. URL: https://www.wessa.net/