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Using the Escape Room game-based approach in chemistry teaching

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Abstract: In recent years, the Escape Room approach has been applied in teaching of various content. Aside from being enjoyable, the Escape Room activities actively involve all students in the class and promote their creative, critical and logical thinking, problem solving, communication and cooperation, as well as positive attitude towards the subject. To encourage the engagement and motivation of ninth-grade students, activities were developed regarding the topic of exothermic and endothermic reactions, through the use of Google Forms and Breakout Rooms option in MS Teams. The application of this approach helps students to master the teaching content in a more interesting way, encourages discussion and cooperation among students. 244 9th grade students from five primary schools participated in the research. Apart from encouraging engagement and motivation among students, one of the objectives of the research was to examine their opinions regarding the implemented Escape Room activities. For this purpose, the motivation of students towards Science Learning (SMTSL) and Activity Perception Questionnaire (APQ-ER) instruments were implemented. The research results, positive atmosphere during the classes, and high students' satisfaction after completing the activities indicate numerous benefits of the implementation of the Escape Room approach in chemistry teaching.

Keywords: game-based learning; exothermic and endothermic reactions; IMI; SMTSL.

INTRODUCTION

A game is a type of play where all participants should follow defined rules.[1] They are usually recreational, but can also be used as a pedagogical tool if they are applied to learning in a particular area. Games in education are often used by teachers who have younger students, although it has been proven that older students also enjoy a well-designed educational game that can stimulate them to

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be more effectively involved in the class.[2] The application of many educational games is mostly focused on improving critical thinking skills in processing various teaching contents in different subjects. They are an excellent method for developing students' creativity and gaining research and problem-solving skills. Numerous studies have been performed in the past on how the usage of educational games affects students' motivation.[3–7] Many of them refer to mathematical and language cognitive skills,[3,5] and some describe the value of computer games as a motivator.[4] Chemistry is also one of the subjects for which educational games have been developed, and one of the most popular topics for their implementation is the Periodic Table of Elements.[7]

The Escape Room approach has become popular around the world in the recent years.[8–10] It has a relatively short history. The first Escape Room activity was organized in Kyoto, Japan, in 2007, as a single room game for teams of 5–6 players.[11] According to Nicholson,[11] Escape Rooms are live-action team-based games in which players (in this case, students) are given tasks, usually to solve a variety of puzzles, in order to escape from the room. This means that, in a limited amount of time, players should accomplish a specific goal determined by the coordinator of the game. Different versions of this activity can be developed, but the main idea is to create a context where players have to solve different tasks as a group within a given time.[12] Having this in mind, in 2019 seminars for professional development of chemistry teachers were held in the Republic of Macedonia and in the Republic of Serbia,[13,14] the aim of which was to educate teachers on how to apply this approach in chemistry teaching.

In contemporary education, Escape Room activities, which are based on game-based learning, offer opportunities related to active learning, self-regulation, fun and social interaction.[15–18] The teachers need to find a way to motivate their students and keep their attention, while developing their 4C skills (creativity, communication, collaboration, critical thinking). To create a good educational Escape Room activity, the teacher needs to effectively link the goals of the game with the goals of the teaching content. Preparing such activity takes time, but once prepared, games can be used many times with slight modifications.[19] Carefully prepared game-based activities should enable greater students' participation and mental involvement, which would then lead to increased motivation and interest in the subject and development of positive attitude toward chemistry.[19] Game-based lesson promotes much greater student engagement than the traditional lesson because students want to win the game.

This approach can be used for elaboration of teaching content in various subjects or topics, and the effects of its implementation in chemistry teaching have been examined in several studies.[20–22] In recent years, the Escape Room approach has become very popular in STEM classrooms. Chantal and Belova[20] conducted a systematic literature review to gain insight into the prevalence of this type of educational games and the need for further development in this field. The authors searched the common databases and analyzed 93 journal articles, book chapters, and conference papers that targeted a specific educational level, were designed for formal educational settings and were aimed at STEM education. 15 out of 93 publications dealt with Escape Rooms in secondary and tertiary chemistry education (12 chemistry activities included experiments or lab-based activities), developed either on a specific topic or a combination of several ones. The results of their study showed that there is a need to develop more easily adaptable Escape Rooms, and provide further evidence regarding the effects of their implementation in the classroom. This in-depth research did not uncover studies that dealt with the topic of exothermic and endothermic reactions and, therefore, it is clear that future research should focus on the implementation of Escape Rooms in primary education, which, due to the age of the students, requires simplicity in the solving of the puzzles.

Still, it is worth mentioning that in order to implement the game-based learning approach, teachers in primary and secondary education need to be educated on how to apply it within the teaching process. First of all, the teacher needs to know how to design such an educational game and carefully plan all the details for its application in the classroom. The game should be prepared before the beginning of the classes and the puzzles should be pre-tested. Teachers should also be aware of the lesson time limit and all Escape Room activities must end before the bell rings.[19]

The application of this approach offers many opportunities to master the teaching content elaborated in primary and secondary education. The idea was to develop creative and interactive lessons, which, apart from the enjoyment, would promote the engagement and motivation to master the teaching content through the game, as well as a more positive attitude towards chemistry among students. It is expected that the Escape Room approach would provide a large number of benefits to students. Apart from the advantages, application of this approach also has disadvantages, such as the limited time to answer the puzzles.[8] If this activity is realized online, problems with the internet connection can be mentioned as a disadvantage, especially when the students use this activity for the first time. Therefore, a special challenge was to see if online teaching, which was dominant in schools during the pandemic, enabled better digital competencies for both students and teachers. Furthermore, conducting Escape Room activities in an online environment implies that students will not be able to engage in practical activities, such as experimenting, or make tactile observations.

EXPERIMENTAL

The aim of the research

The objectives of this research were to apply an innovative and creative approach in chemistry teaching to increase the engagement and motivation of 9th grade students in reviewing the concepts of exothermic and endothermic reactions. The primary idea of the research was to, by using the Escape Room activities, encourage students to participate actively in the classes and to increase their interest and motivation to learn chemistry. The implementation of Escape Room activities, besides helping the students to master the teaching content in a more interesting way, was also aimed at encouraging discussion and collaboration within the group, as well as competition among groups. In this way, students had the opportunity to improve their communicational skills, and develop their creative, critical and logical thinking, as well as a positive attitude toward chemistry classes.

In addition, after the end of the classes, the opinion of the students regarding the conducted activities was examined.

The sample

In order to examine whether the application of Escape Room activities affects the engagement and motivation of 9th grade students in reviewing the topic of exothermic and endothermic reaction, the research was conducted in five primary schools from cities in different regions of the country. The research included a total of 244 9th grade students (13–14-years-old) who attend classes in different languages of instruction, *i.e.*, 195 in Macedonian and 49 in Turkish. The study was conducted in accordance with school rules, and the students and their subject teachers agreed to voluntarily participation. Collection of students' opinions after completing the activities was anonymous using Google Forms. A total of 193 students (123 girls and 70 boys) filled in the APQ-ER items, and 119 students (72 girls and 47 boys) responded to the SMTSL items.

Design

The research was divided into several phases:

1) preparatory phase (preparation and testing of the puzzles),
2) delivering the lesson using Escape Room activities (reviewing relevant concepts from this topic),
3) distribution of Activity Perception Questionnaire for Escape Room activities, APQ-ER (filling in the questionnaire by the students in order to express their opinion regarding the implemented activity),
4) distribution of Students' Motivation toward Science Learning questionnaire, SMTSL (examining students' opinions about their motivation for learning chemistry) and
5) analysis of the obtained data using the SPSS Statistics 26 software package.

This research consisted of reviewing the main concepts related to the last topic of the 9th grade chemistry curriculum regarding exothermic and endothermic reactions by using the Escape Room game-based approach. These activities were conducted during April–May 2021. Considering the fact that the last school year in the Republic of Macedonia took place online, this activity was prepared and realized with the help of MS Teams and Google Forms.

Preparing Escape Room puzzles is time-consuming, whether working face-to-face or online. Thus, for example, if the activities are done in the classroom, boxes, padlocks, envelopes, markers, sheets of paper for solving puzzles, *etc.*, are needed. All of this should be prepared by the teacher before the class starts. On the other hand, these things are not required when working online, but in this case it is necessary to create online puzzles (for example, through Google Forms) and profound skill of the teacher to lead the groups of students (divided into breakout room) is required.

Namely, at the beginning of the class, students were divided into several groups using the breakout rooms option by MS Teams. Depending on the number of students in the class, they were usually divided into 5–6 groups of 3–4 students. With the help of the subject teacher, the students were previously divided into groups (the selection of students was made prior to the class), depending on their achievement in chemistry. This was done to ensure a fair as competition as possible, and to encourage communication and mutual assistance between students within the group. When all the students were in their group, the researcher sent them the link from the Google Forms and she entered all the groups to check on the students and offer help if needed. One student wrote down the names of all the members in the group and shared his/her screen with other students within a group. The students in the group were able to collaborate, communicate, discuss and share ideas freely. When they were convinced of the correctness of the answers, one member of the group wrote the correct answers in the empty fields of the form (Google Forms) and pressed the submit option. In such a way, a competition between the groups was felt because students had a time limit – they had to finish solving the puzzles in 30 min. In fact, the duration of a school lesson is 40 min, but some time is needed at the beginning and at the end of the lesson for explanations and/or reflection. If students had the whole class at their disposal, they would have more time to think about solving the puzzles.

Description of the games

The Escape Room activities that were prepared for this research consisted of three puzzles the students had to answer to win, *i.e.*, they needed to solve the puzzles and "escape". These puzzles were prepared by the authors taking into account the learning objectives defined in the ninth-grade chemistry curriculum. The Escape Room activity along with these puzzles were piloted among 77 nineth-graders.[23]

The first puzzle (Fig. 1), given as a maze, required an answer to a simple question, but the way the question was posed arouses students' interest.[24]

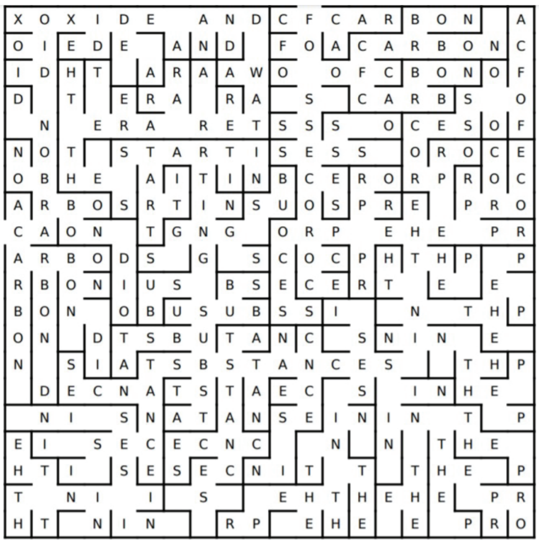

Fig. 1. Puzzle 1 – Maze.

Students had to find the way out of the maze puzzle and, in that way, to discover the question they needed to answer. If the answer was correct, the code had been discovered. In our case, the question was: Carbon dioxide and water are the starting substances in the process.

In the second puzzle (Fig. 2) chemical formulas of several compounds were given. It was necessary to find the connection between them to discover the code. First, students had to find out which substances are the reactants, and which are products, then they had to write the chemical equation and finally balance it by using stoichiometric coefficients. When they had finished balancing the chemical equation, the inserted numbers revealed the code. The balanced chemical equation was: $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$.

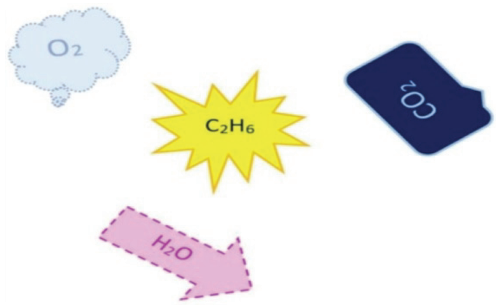

Fig. 2. Puzzle 2 – Chemical formulas of compounds.

The third puzzle consisted of three multiple choice questions. Each question had four options, one of which was the correct answer and other three were distractors (Fig. 3). The aim of this game was to repeat some important segments of the exothermic and endothermic reactions topic. After the students had answered the questions, they were supposed to discover the code using the symbols in the table.

	A	B	C	D
1	@	☼	♫	♥
2	♫	♥	@	☼
3	♥	@	☼	♫

@ = 1 ☼ = 2 ♫ = 3 ♥ = 4

1. An example of an endothermic reactions is:
A. Neutralization
B. Combustion
C. Replacement
D. Electrolysis

2. What is released in the process of photosynthesis?
A. Carbon dioxide
B. Carbon monoxide
C. Oxygen
D. Hydrogen

3. Evaporation is an:
A. Endothermic reaction
B. Endothermic process
C. Exothermic reaction
D. Exothermic process

Fig. 3. Puzzle 3 – Multiple choice questions.

The first question was: An example of an endothermic reactions is: a) neutralization, b) combustion, c) replacement or d) electrolysis. The second question was: Which of these compounds represent a product of photosynthesis: a) carbon dioxide, b) carbon monoxide, c) oxygen or d) hydrogen. The third question was: Evaporation is: a) endothermic reaction, b) endothermic process, c) exothermic reaction or d) exothermic process.

Instruments

One of the aims of this research was to examine students' opinion about the conducted activities during the class. For this purpose, students were administered a questionnaire in which they expressed their opinions on how interesting and enjoyable the activities were, stated the value and the usefulness of those activities in the teaching and learning process, and shared their beliefs about their engagement and effort that they had invested in the activities. Two questionnaires were used: Activity Perception Questionnaire (APQ-ER), as part of the Intrinsic motivation inventory (IMI)[25] and Students' Motivation Toward Science Learning (SMTSL).[26]

The IMI questionnaire was used to assess students' subjective opinions and experiences related to certain activities conducted in the classroom. It was a Likert type questionnaire, where 1 means the respondent does not agree with the statement at all and 7 means that (s)he completely agrees with the statement. The instrument assesses students' interest/enjoyment, perceived competence, effort, as well as the importance of the activity, value/usefulness, felt pressure/tension, and perceived choice while performing a given activity. Recently, a seventh subscale was added to tap the experiences of relatedness. This questionnaire has been used in research in various field, such as: sport,[27] information and communication technology,[28] science education,[29] first language and mathematics learning,[30] *etc.* For the purposes of this study, the APQ-ER was used, which is part of the IMI questionnaire. It was constructed using items from four subscales, each comprised of 4–8 items: interest/enjoyment (*e.g.*, While I was doing this activity, I was thinking about how much I enjoyed it.), value/usefulness (*e.g.*, I would be willing to do this again because it has some value to me.), effort/importance (*e.g.*, It was important to me to do well at this task.), and pressure/tension (*e.g.*, I felt very tense while doing this activity.), and contained a total of 23 items.

The SMTSL questionnaire is also a Likert type questionnaire and contains 35 items, divided into six categories related to students' motivation to study science: self-efficacy (*e.g.*, I am sure that I can do well on science tests.), active learning strategies (*e.g.*, When new science concepts that I have learned conflict with my previous understanding, I try to understand why), science learning value (*e.g.*, I think that learning science is important because I can use it in my daily life.), performance goal (*e.g.*, I participate in science courses to perform better than other students.), achievement goal (*e.g.*, During a science course, I feel most fulfilled when I am able to solve a difficult problem.), and learning environment stimulation (*e.g.*, I am willing to participate in this science course because the students are involved in discussions.). The participants were asked to give their opinions on each of the offered statements, so that they will express the degree of agreement with a certain statement by circling one of the offered possibilities (1–5), as follows: 1, if (s)he does not agree with the statement at all; 2, if (s)he disagrees with the statement; 3, if (s)he does not have an opinion/idea about the statement; 4, if (s)he agrees with the statement, and 5, if (s)he completely agrees with the statement. This questionnaire is well known in the literature and has been used in many studies to examine the students' motivation to study physics,[31] biology,[32] Greek,[33] *etc.*

In the statements of both questionnaires, the word science was replaced by the word chemistry.

Procedure and data analysis

For the purpose of the present research, the SMTSL questionnaire and the four subscales from the IMI questionnaire were translated from English to Macedonian. Five university professors experienced in educational research from two faculties were engaged in the translation procedure. All five versions of the two questionnaires were compared and the disagreements were resolved. The translated questionnaires were then prepared in Google Forms, and the students filled them out individually and anonymously during the last 5–7 min of the lesson. Students were told that the questionnaire would not affect their grade and that there were no correct and incorrect answers. Furthermore, they were encouraged to give an opinion on each statement and were explained that this will be used for scientific purposes only. The obtained results from both questionnaires were analyzed using the software package SPSS Statistic 26.

RESULTS AND DISCUSSION

In order to examine the internal consistency, taking into account the results of all the items for each subscale, the results were analyzed and the mean, standard deviation and the Cronbach' alpha reliability coefficient were calculated (Tables I and II). To score the APQ instrument, the following procedure was conducted. First, reversed scores were calculated for the items for which an R is shown after them by subtracting the item response from 8. The letter R indicates that the given statement is written with the opposite meaning from that of the other statements in that category. After that, subscale scores were calculated by averaging across all of the items on that subscale and were used in the analyses of this study.

TABLE I. Means, standard deviations and Cronbach's alpha reliability coefficient for APQ-ER instrument

Scale	Number of items	APQ-ER		
		Mean	*SD*	Cronbach's alpha
Interest/Enjoyment	6	6.09	1.46	0.889
Value/Usefulness	8	6.01	1.38	0.994
Effort/Importance	5	5.07	1.90	0.646
Pressure/Tension	4	2.25	1.78	0.647
Total	23	5.17	2.12	0.837

TABLE II. Means, standard deviations and Cronbach's alpha reliability coefficient for SMTSL instrument

Scale	Number of items	SMTSL		
		Mean	*SD*	Cronbach's alpha
Self-efficacy	7	4.00	1.16	0.819
Active learning strategies	8	4.32	0.89	0.879
Science learning value	5	4.12	0.98	0.832
Performance goal	4	3.17	1.52	0.825
Achievement goal	5	4.26	0.97	0.806
Learning environment stimulation	6	3.87	1.19	0.822
Total	35	4.01	1.16	0.901

As can be seen from Table I, the Cronbach' alpha reliability coefficient for the whole APQ-ER instrument was 0.837, ranging from 0.646 to 0.994 for the subscales. Following the cutoff criteria of Cohen,[34] it can be concluded that

Cronbach's alpha reliability coefficient revealed acceptable internal consistency for all four subscales, which was also confirmed by Choi[35] and Monteiro.[30]

From the obtained results of the questionnaire, it could be concluded that most of the students found the activity as fun, enjoyable and interesting. Namely, on a scale from 1 to 7, the agreement with the items from the interest/enjoyment subscale, *i.e.*, the mean was 6.09. The mean for the value/usefulness subscale was also high (6.01). The students felt that this activity was important for their success and progress, but it could also enable them to achieve better results and improve their attention during the class. The nature of the Escape Room activities, which is based on teamwork, communication, cooperation and problem solving, certainly contributes to this. This activity affects not only the engagement and motivation of students, but also touches the cognitive and affective domain of leaning.

A lower value (5.07) was observed for the items of the effort/importance subscale. The value is shifted to the right from the mid-point of the scale, but this shift was not as pronounced as in the previous two subscales. Most of these items refer to the students' estimation of how much effort they have put into the activity, *i.e.*, in solving the three puzzles. Based on the results, it could be assumed that the puzzles were not too difficult to master, and due to the fun nature of the activity, the students did not feel like they were in a usual" review class. However, an item mean value of 6.20 indicates that it was important for the students to complete the task successfully. It should be mentioned here that negatively formulated items could cause some confusion among students.

Considering the fact that the students were encountering this type of activity for the first time, the aim was to examine whether the students were tense and nervous during this class. The analysis of the students' answers to the questionnaire showed that they were not nervous during the class, but relaxed, in spite of the competitive nature of the activity, as well as the limited working time and problems with the internet connection, could cause some tension. This can be concluded from the mean (2.24) obtained for the last subscale, pressure/tension.

From Table II, the value for the Cronbach' alpha reliability coefficient for the whole SMTSL instrument was 0.901, ranging from 0.806 to 0.879 for the six categories. Dermatzaki[33] and Tsai[31] also obtained high values for the Cronbach's alpha reliability coefficient for this instrument.

Students' motivation was estimated based on the means of their scores for each subscale and for the whole questionnaire.[36] According to the Cavaş's classification system,[37] a high level of motivation includes means between 4.41 and 5.00, a medium level of motivation includes means between 4.40 and 3.39, and a low motivation includes means lower than 3.38. From the results presented in Table II, it could be seen that students had medium motivation towards chemistry learning since their mean score was 4.01. The mean for each subscale were considered medium as well, except for the performance goal scale where their motivation was low (3.17 < 3.38).

CONCLUSIONS

The Escape Room game-based approach was applied in order to increase the engagement and the motivation of 9th grade students in reviewing the concepts of exothermic and endothermic reactions. In addition, the applied approach was used to improve their communication skills, encourage their creative, critical, and logical thinking, and promote their ability to solve problems. Nowadays this approach is often applied in teaching various subjects, and it arouses additional interest for both the students and the teachers.[38-41]

The research was conducted on a total sample of 244 students from five schools located in different cities. One of the main goals of the research was to examine the students' opinions regarding the implemented activities, and for that purpose the data were collected by SMTSL questionnaire and APQ-ER, which was constructed using items from the IMI questionnaire. The analysis of the collected data showed that this approach in a great extent affects the improvement of teaching. Students were more engaged during the lessons and actively participated in all activities. In this way they were more motivated and more satisfied with the achieved results. Moreover, the atmosphere in the class was very positive and it was visible that students were enjoying the puzzles.

It is worth mentioning some of the limitations of this study. The students participating in the research encountered these Escape Room activities for the first time, so they may have needed some time to cope at first, but the collected data showed that they were not nervous while solving the puzzles. However, the students' answers to the Google Forms in solving the puzzles were received in a relatively short time from the beginning of the class and there was at least one winner in each class. This, in turn, means that the puzzles were solvable within one school class and with a successful strategy and cooperation within the group, the answers could have been reached faster.

In addition, the study was conducted only on 9th grade students on one topic. More such activities related to various topics are needed to obtain more relevant results and to draw more comprehensive conclusions about the applicability of Escape Room activities in chemistry teaching.

И З В О Д

ПРИМЕНА ПРИСТУПА ЗАСНОВАНОГ НА ИГРИ *ESCAPE ROOM* У НАСТАВИ ХЕМИЈЕ

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Последњих година у настави посвећеној различитим садржајима примењује се приступ према правилима игре *Escape Room*. Осим што су активности пријатне, оне у игри

Escape Room активно укључују све ученике у разреду и покрећу њихово креативно, критичко и логично мишљање, решавање проблема, комуникацију и сарадњу, као и позитиван однос према предмету. Да би се подстакло ангажовање и мотивација ученика деветог разреда, развијене су активности на тему егзотермне и ендотермне реакције, помоћу апликације *Google Forms* и *Breakout Rooms* у *MS Teams*. Примењени приступ помаже ученицима да на занимљивији начин савладају наставне садржаје, подстиче њихову дискусију и међусобну сарадњу. У истраживању је учествовало 244 ученика 9. разреда из пет основних школа. Осим подстицања ангажовања и мотивације ученика, један од циљева истраживања био је и испитивање њиховог мишљења о реализованим активностима у оквиру игре *Escape Room*. Примењена су зато два инструмента: упитник за испитивање мотивације ученика за учење науке (SMTSL) и упитник о перцепцији активности (APQ-ER). Резултати истраживања, позитивна атмосфера током наставе и велико задовољство ученика након завршених активности указују на бројне предности примењеног приступа у настави хемије.

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