Chemical Escape Room

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Abstract

The following article describes the design of a digital application "Chemical Escape Room" for learning chemistry through virtual entertainment. The article discusses the usage of modern application solutions in the field of education. The results of the test to check the knowledge of people testing the game before and after the game, created as part of the project, are also presented. There are also reviews of lecturers from the Faculty of Chemistry, Technical University of Gdańsk, who had the opportunity to play the game.

Keywords: escape room, chemistry, educational game, education, science, point and click, puzzle

1. Introduction

The process of using games in different areas of life is called gamification. In the field of education it is called edugamification, which means the deliberate design of the entire didactic process, including the methods of measuring and evaluating the effects, in order to create an educational space that thrives on the principle of gamification. In this way, students are provided with clear and transparent rules of action, a flexible level of difficulty tailored to individual abilities, quick feedback, and the opportunity to achieve both long- and short-term goals [1].

Currently, the usage of computer games is becoming more and more common. Simulation, sports, role-playing and strategy games help improve eye-hand coordination, concentration and spatial orientation, train memory, develop perceptiveness, provoke logical thinking, teach to make decisions, make choices and anticipate consequences of their actions. Games from various fields of knowledge (mathematics, logic, nature, geography, ecology, foreign languages) help to acquire knowledge and interest a child in a given topic, at the same time constituting a form of

interesting fun. Serious Games have become an important didactic tool used in military training (e.g. learning how to maneuver a tank, simulating platoon fights, learning war tactics) and medical training (e.g. virtual operating rooms for future surgeons, games used in patient rehabilitation or promoting healthy lifestyles and healthy eating) [2].

Also in school education, games are gaining popularity, they find their way into school reading lists and "learning through fun". Times of pandemics and remote learning have only confirmed that education of the youngest generations as well as students cannot do without digital teaching aids. The market offers teachers many free applications that either allow you to design your own educational games or contain educational games ready to use . Developers of games or engines for such games grant free licenses, usually allowing almost unlimited free use. The choice of paid educational games is huge, thanks to which teachers can find a game almost "on any topic", i.e. appropriate for the given didactic content [3].

As mentioned above, the success in applying computer games in education is rooted in the edutainment strategy combining entertainment with didactics. It is a good starting point for the application of virtual forms of recreation in the process of education, since play constitutes the basic activity and the essence of the proper development of every child. Virtual entertainment realized mainly through computer games has numerous positive values. Undoubtedly, they include activating influence on brain work, increasing the possibility of associating facts and memorizing. Thanks to its specific character, virtual spaces created in games can be a great tool for shaping spatial imagination, improving many skills and help in advanced analysis of objects on a plane. These features can activate the brain by increasing the associative abilities and intellectual capacity in all players, even the elderly. However, it should be remembered that the above positive influence of games is possible only during their appropriate and proper use. First of all, it should be noted that computer games are not only for teenagers [4].

There are many educational games available in the market. We can find applications that help in learning many issues. Such software seems to be very attractive especially for the youngest, because learning through play is very effective and encouraging. An example of such a game can be Koziołek Matołek Wynalazca created by Aidem Media. In the game you will find a set of interesting, engaging games and educational activities starring the lovable Matołek the Goat. Our hero wants to get

a secret recipe for getting A's in school. To do it, the youngest computer users have to help him solve tasks from several different fields of knowledge. Together with Matołek the Goat children learn arithmetic and the alphabet, get to know such issues as: time and the functioning of clocks, construction of machines and devices, weather shaping factors and various measurements: weight, length and volume.

Significant emphasis was placed on mini games in which more than one player can take part, i.e. the Omnibus quiz and the "Za-mee-k" board game. The first one is a general knowledge quiz including such topics as: geography, world of animals and plants, sports, spelling and English language. The board game, on the other hand, is a race to the castle with many surprises. Both games can be played by several players, which makes them a perfect entertainment for the whole family or a group of friends. The program exercises reflexes, memory and logical thinking [5].

An educational game that focuses on chemistry is Professor Why™ Chemistry. It is a Polish one that uses augmented reality (AR) technology to show children the world of science in an attractive and understandable way. The player has test tubes, menzies and chemical reagents at their disposal. Professor Why™ Virtual Chemistry Lab allows you to perform experiments on your own in a completely safe way on your computer. The game has 55 grouped experiments and animated scenes with interesting facts from the life of famous chemists [6].

Nowadays more and more people, especially teenagers, are using computer games. The aim of the project was to create a friendly application dealing with selected issues in the field of chemistry. The project itself, apart from its didactic function, was intended to promote both the Gdansk University of Technology and the Faculty of Chemistry itself. Methods combining learning and fun are characterized by remarkable effectiveness. Students wanted to create a game with a clear interface and an interesting storyline, based on a popular contemporary entertainment such as escape rooms.

Escape rooms, also known as puzzle rooms, are quite a rapidly growing field of entertainment that provides an unforgettable experience and is a great way to spend time. Each room is a different story set in a specific category that can be selected to suit your preferences [7].

Usually the aim of escape room games is just to have fun and spend time with friends or family. The students' idea was to transfer the fun into the virtual world and use logical puzzles in such a way as to present chemical aspects in an interesting and comprehensible way. In an innovative way, they managed to create an application for Windows and Mac describing the discoveries of four famous Polish scientists: Ignacy Łukasiewicz, Maria Skłodowska-Curie, Karol Olszewski and Jan Czochralski.

2. Used technologies

Two programs were used to create the game:

- TyranoBuilder- a commercial visual novel game development software that is used to create web applications, as well as applications for Windows, Mac, Android and iOS.
- FireAlpaca- a free digital painting software that is compatible with both Mac and Windows systems. Used to rework and create graphics used in the game.

Graphics used in the game were made by the students themselves and licensed for free from the following websites: pexels, pixabay, freepik. The photos used to create the game were taken by the students themselves under the supervision of the client. Some of the photos were given to them directly by the client.

3, Game Description

The created single player point and click game is available in two language versions: Polish and English. After selecting the language, the player is shown the main menu with the option to start a new game or load a save game.

The game starts by showing the manual as shown in Figure 1, immediately after reading the instructions the player is introduced to the game' plot.

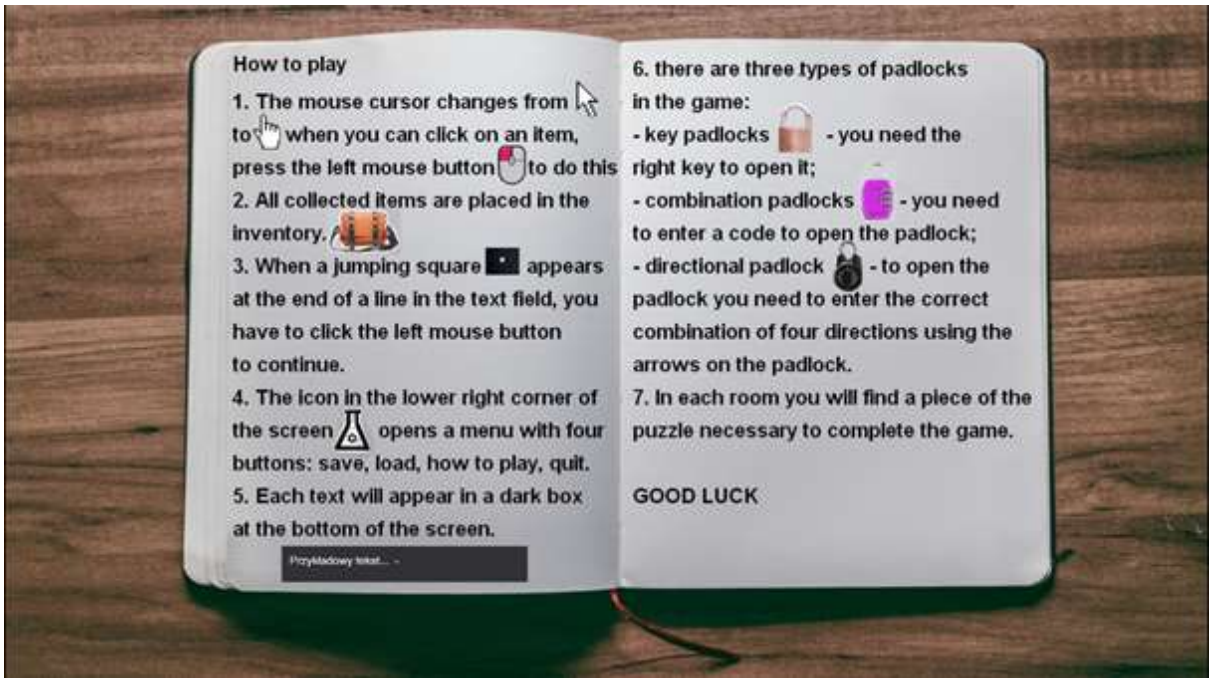

Fig.1. Game manual

The action begins in a room dedicated to Ignacy Łukasiewicz, who constructed the first oil lamp and distilled crude oil [8]. After collecting all the items in the room, the player has an opportunity to solve a quiz. The quiz tests the player's knowledge about the experiment that made the scientist famous. The quiz is based on matching the pictogram to the displayed text, both correct and incorrect answers are visually indicated to the player. The first question from the first quiz is shown in Figure 3. The quiz is a feature found in every room. The tests created by the player continuously check the information that the player has managed to assimilate. If necessary, instructions for the experiment are available to the player from the experiment screen, and can be read at any time between attempts to solve the quiz.

Fig.2. Room dedicated to Ignacy Łukasiewicz

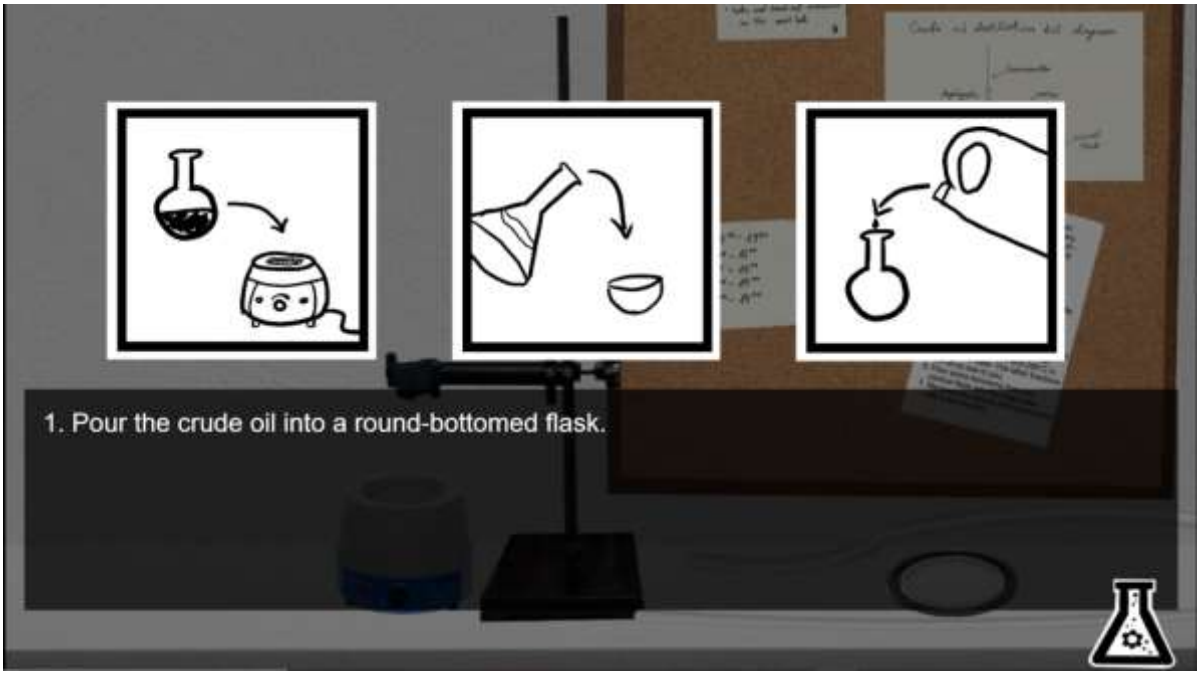

Fig.3. Example of a quiz question

After completing the quiz, the player proceeds to the next location, a hallway connecting the first and second room. The player must wear a protective suit to keep from harmful radiation and then proceeds to the room.This room is dedicated to Maria Sklodowska-Curie, a Polish scientist who won two Nobel Prizes in chemistry and physics for the discovery of radium and polonium [9]. There was added a filter imitating the mask of a protective suit as a visual effect. An additional element is also a pocket Geiger-Müller counter, which we can see in the upper left corner of the screen. The counter pointer changes its position depending on how close we are to the radiation source.

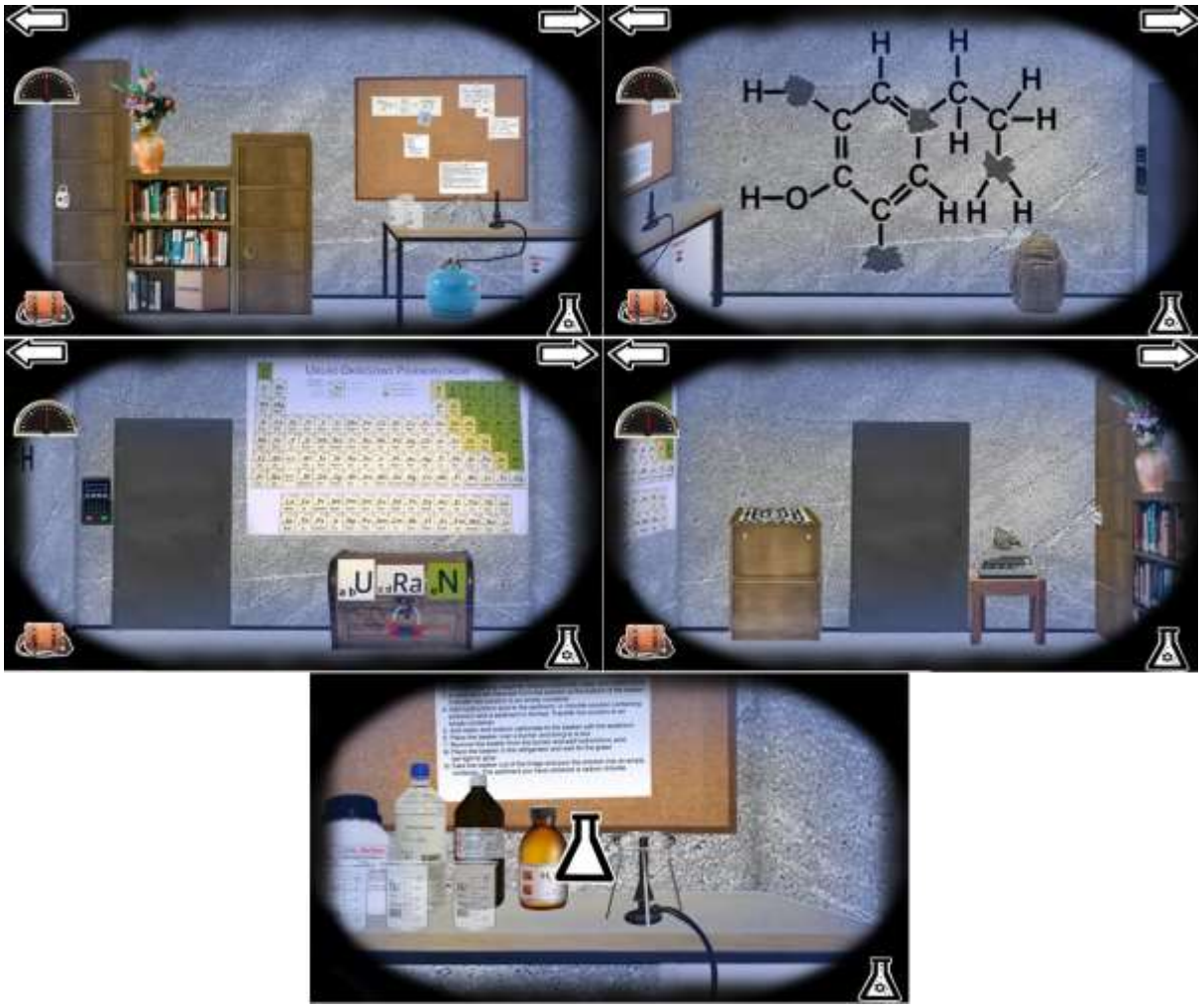

Fig.4. Room dedicated to Marie Skłodowska-Curie

Another element that distinguishes Maria Skłodowska-Curie's room from the previous one is a mini game in the form of a maze. To successfully complete it, you need to guide the red ball to the hole in the middle of the screen. When the player

manages to collect all the necessary items and complete the quiz, they will move on to the next room by entering the appropriate code on the terminal.

After taking off the suit the player enters a room dedicated to Karol Olszewski, who was the first person to succeed in liquefying oxygen [10]. The mechanics of this room is identical to the previous ones, except for two elements: in the room you can find a working laptop and a directional padlock, which can be opened by entering a combination of four directions by clicking the arrows in the right order. In the laptop, on the other hand, you will find all the documents you need to complete the game, such as the instructions needed to do the experiment and the hints on how to open the directional padlock. In the room you can also find a mini game. It is about guiding key which is necessary to leave the room through the labyrinth.

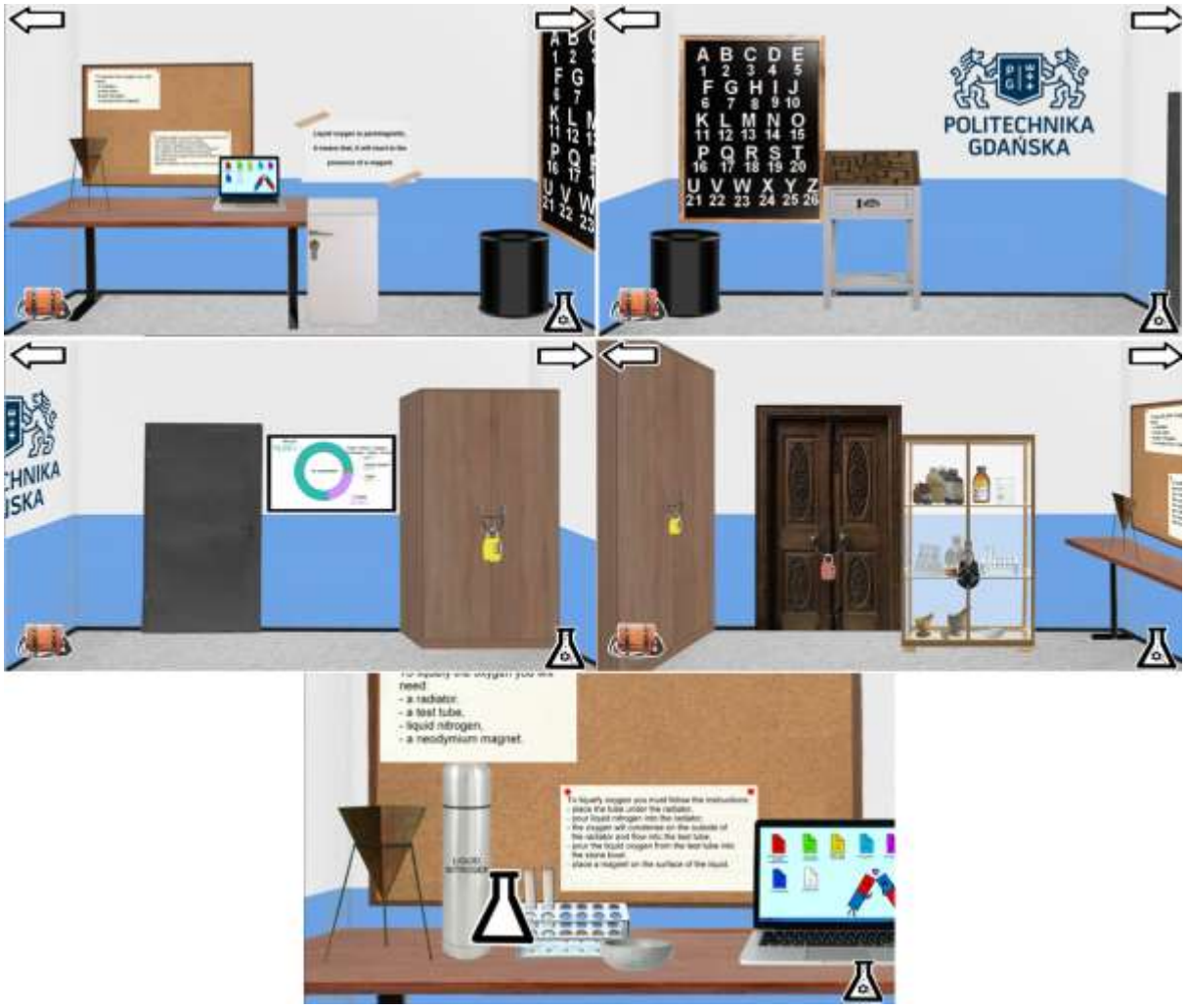

Fig. 5. Room 3 dedicated to Karol Olszewski

Another room is dedicated to Jan Czochralski, the most cited Polish scientist, the man who developed the widely used method of obtaining silicon monocrystals. This room is distinguished by an additional experiment involving a reaction to form aluminum iodide.

Fig.6. Room 4 dedicated to Jan Czochralski

After solving the puzzles and the quiz, the player will get to the next room (Figure 7), where he/she will have a chance to read a short fragment of biographies of all the scientists player met during the game, and then the last puzzle will be waiting for them.

Fig.7. Room with short biographies of scientists

Each room features logical puzzles that combine fun with science. In the rooms we will find elements necessary to complete such as fragments of notes, instructions necessary to do experiments or other items needed to solve the puzzles waiting for the player. An integral part of the game are also short tests that check the player's knowledge on an ongoing basis. At each stage of the game, the player can check what items he or she has collected by clicking the inventory icon located in the lower left corner of the screen. Padlocks are also an important element of the game, there are three types of them: keyed padlocks, combination padlocks and directional padlock.

4. Surveys and tests

A group of 50 people between 10 and 62 years old were subjected to Test 1. Test 1 was created when the students completed the design of the first stage of the game. This was to test the didactic value of the application they were developing. The results showed that the developed game fragment has educational properties, which influenced the decision not to conduct tests after each newly created stage of the game. It was finally agreed that the state of knowledge will be checked after the complete passage of the game.

Test 1, seen below, was administered to volunteers both before and after completing the first stage of the game in order to compare their acquired knowledge.

A maximum of 10 points could be obtained (correct answers are marked in bold). Test participants were not informed about their scores after their first attempt to solve the test.

1. What did Ignacy Lukasiewicz get from crude oil?

a) mineral oil

b) kerosene

c) mazout

2. As a result of Lukasiewicz's experiment, the substance when burned:

a) burns with a pure flame

b) does not burn at all

c) burns and smokes

3. At what stage of Lukasiewicz's experiment are the boiling stones thrown in:

a) initial

b) final

c) not at all

4. What ink was used to hide important messages?

a) disappearing

b) unsympathetic

c) sympathetic

5. At what minimum temperature does the liquid petroleum fraction boil?

a) 200

b) 170

c) 150

6. At what maximum temperature does the liquid petroleum fraction boil?

a) 250

b) 220

c) 270

7. What is a heating mantle used for?

a) to heat

b) to cool

c) for stirring

8. Which chemical element combines with hydrogen in the presence of diffuse sunlight?

a) bromine

b) chlorine

c) silver

9. Match the element symbol to the description : " ... in contact with water and acids it ignites, often explosively. It is a very soft metal. It can be cut with a knife, like cheese."

(a) lithium

(b) sodium

(c) potassium

10. What chemical symbol do the elements sodium and bromine have:

(a) S and Rb

(b) Só and B

(c) Na and Br

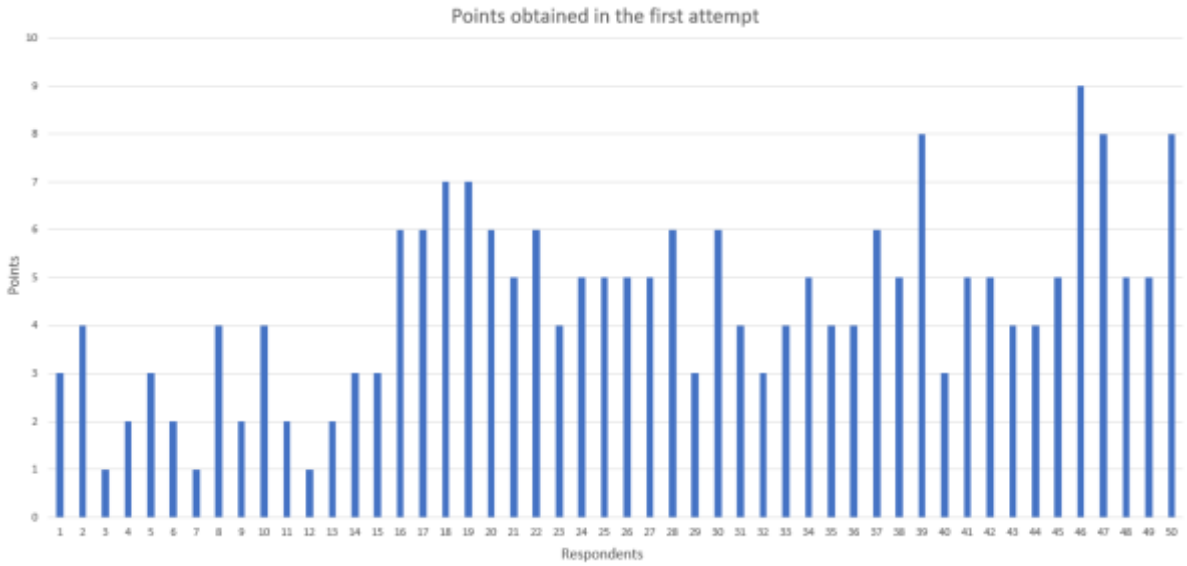

Figure 8: Graph of the number of points obtained when the test 1 was solved for the first time

On the first attempt at Test 1, half of the respondents scored 5 or more points.

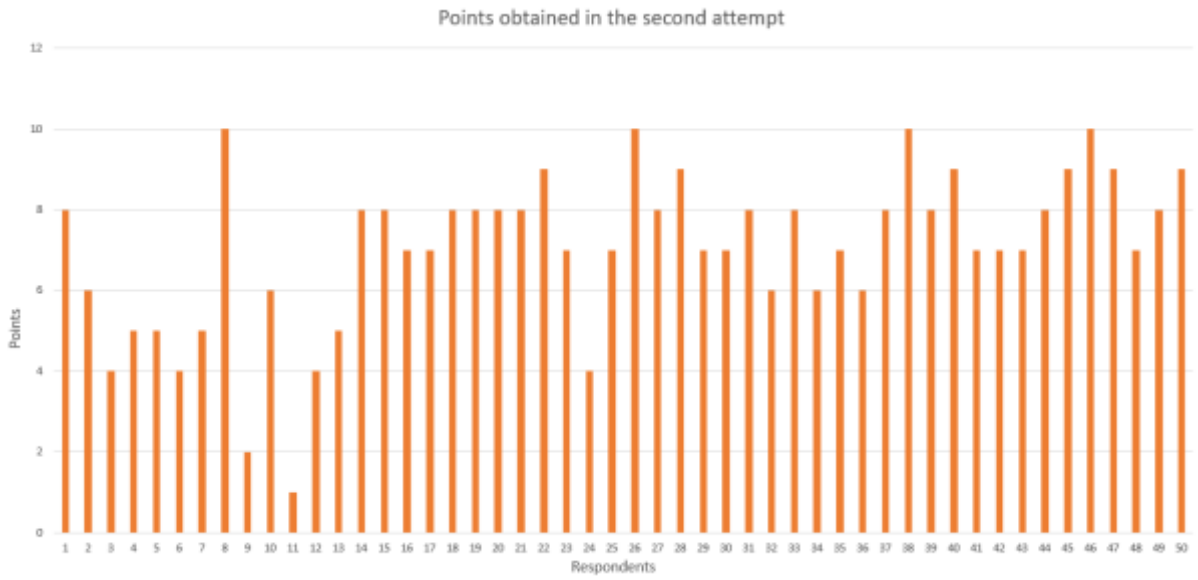

Figure 9: Graph of the number of points obtained when the test 1 was solved secod time

On the second attempt at Test 1, the number of respondents scoring below 5 correct answers dropped dramatically to 6 respondents.

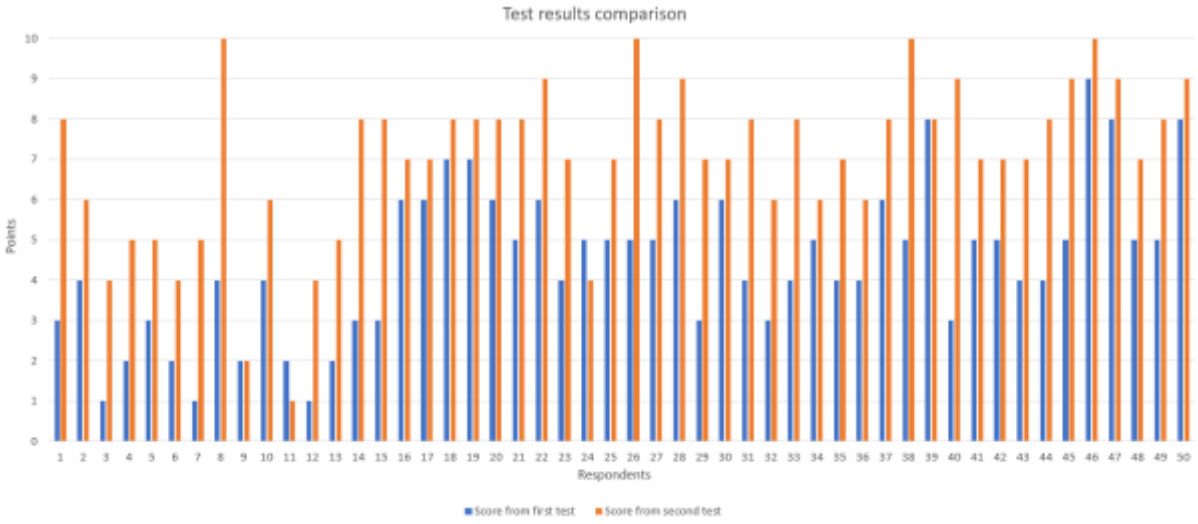

Figure 10: Comparison of results (number of points received) for test 1

A total of 50 subjects took Test 1. The obtained data were sorted into age ranges:

- Compartment I - 10-15 years (15 persons)
- Compartment II - 16-30 years (29 participants)
- Compartment III - 31-40 years of age (3 persons)
- Compartment IV - 40+ years of age (3 persons)

Table 1. Average number of correct answers received on test 1 (about the first room) by age group

Age range (years)	First attempt	Second attempt
10 - 15	2,47	5,40
16 - 30	5,03	7,55
31 - 40	7,33	9,33
40+	7,67	8,00

In each age group, the average number of correct answers increased after completing the first room of the game, proving that the first room of the Chemistry Escape Room game has didactic properties.

The same group of people was given Test 2, seen below, testing knowledge both before and after completing the entire game. As in the case of the first test, for each correct answer the test participant could receive 1 point. The maximum possible number of points was 10. This time the participants were not informed about their results either

1. What did Ignacy Lukasiewicz get from crude oil?

a) mineral oil

b) kerosene

c) fuel oil

2. At what minimum temperature does the liquid fraction of crude oil boil?

a) 200

b) 170

c) 150

3. What elements did Marie Skłodowska-Curie discover?

a) magnet and zinc

b) radium and polonium

c) bismuth and uranium

4. What happens when sodium carbonate, water, and sulfuric acid VI are added to uranium ore?

a) a precipitate is formed

b) nothing

c) smoke is emitted

5. Which gases were successfully liquefied by Karol Olszewski and Zygmunt Wróblewski?

a) argon and xenon

b) helium and hydrogen

c) oxygen and nitrogen

6 What device is used in Karol Olszewski's experiment?

a) pipette

b) radiator

c) fume cupboard

7. What did Jan Czochralski succeed in creating?

a) silicon single crystal

b) potassium oxide

c) aluminium iodide

8. To what temperature should the furnace be heated in Jan Czochralski's experiment?

a) 2100°C

b) 1200°C

c) 1500°C

9. Which scientist received two Nobel prizes?

a) Maria Skłodowska-Curie

b) Jan Czochralski

c) Karol Olszewski

10. Who is the most cited Polish scientist?

a) Jan Czochralski

b) Maria Skłodowska-Curie

c) Ignacy Łukasiewicz

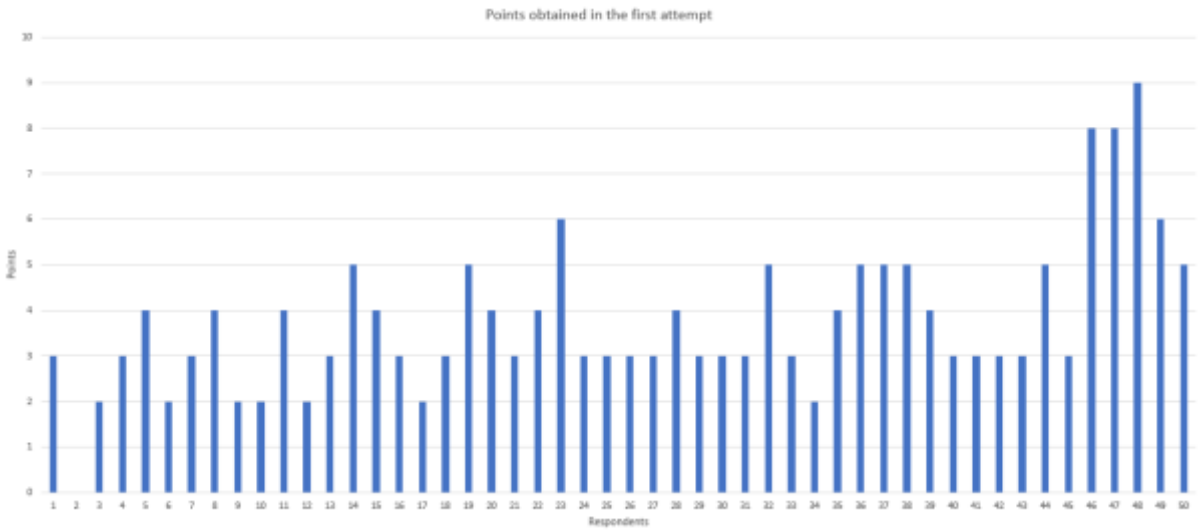

Figure 11: Graph of the number of points obtained on the first attempt at test 2

On the first attempt at Test 2, less than half of those surveyed scored 5 or more correct answers, as shown in Figure 11.

Figure 12: Graph of the number of points obtained on the second attempt at test 2

On the second attempt at Test 2, the number of respondents who scored below 5 correct answers dropped dramatically to 4 respondents.

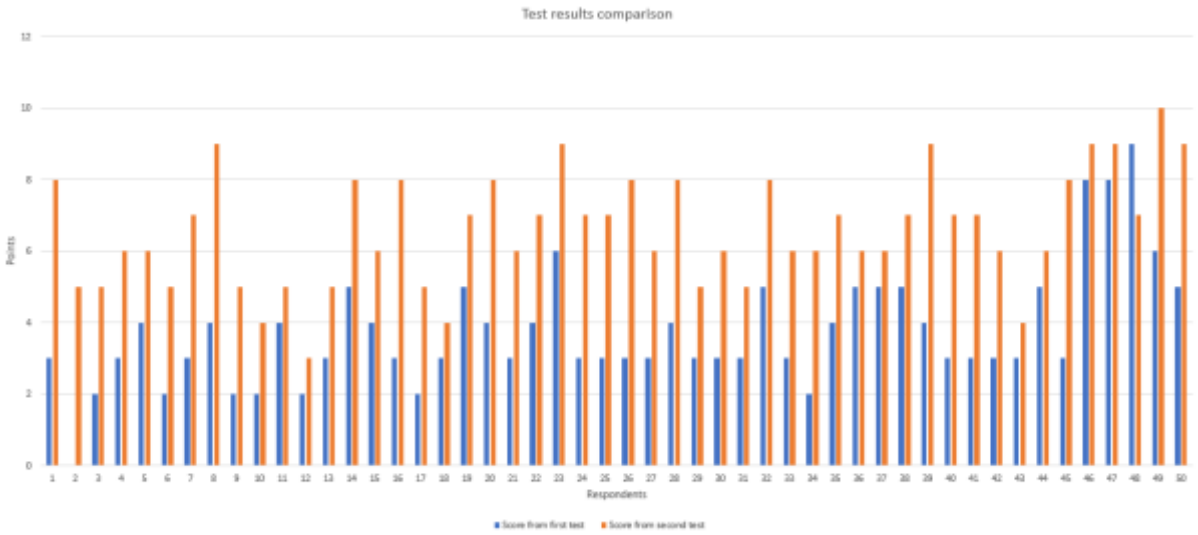

Figure 13: Comparison of results (number of points received) of test 2

Table 2 shows the mean value of the scores obtained by the participants both before and after going through the game.

Table 2. Average number of correct answers received on test 2 by age group

Age range (years)	First attempt	Second attempt
10 - 15	2,87	5,80
16 - 30	3,62	6,59
31 - 40	6,33	8,67
40+	6,67	8,67

It can be seen that in each age group the average number of correct answers increased after completing the game, which proves that Chemical Escape Room game has educational properties.

5. Reviews, expert opinions

“The game is a valuable teaching tool. It allows you to familiarize players with Polish scientists and inventors in an accessible and interesting way.

It presents interesting experiments that are difficult to present or carry out on your own for safety reasons. Especially the preparation of iodine vapors makes an impression.

The presented puzzles require knowledge and skills from various fields of science, but the aids placed on the boards support the player. The use of photos of places and objects from the campus of the Gdańsk University of Technology also makes this game a valuable promotional tool." - dr inż. Anna Kuczyńska- Łażewska.

"In my opinion, the game "Escape room" contains an interesting form of presenting educational content and is a potential tool that can be used to promote the Faculty of Chemistry. The game contains interesting elements of laboratory equipment and gives the opportunity to perform "on-line" experiments and observe their effects. Chemical riddles allow you to learn about interesting chemical reactions and, above all, the characters of famous inventors, the game contains a number of puzzles, codes, padlocks that allow us to move between rooms. Particularly noteworthy is the large number of real photos taken at the Faculty of Chemistry and the drawings made by the authors themselves. The drawings complement the content of the game very well and are an interesting addition. I believe that the game was made conscientiously and required a lot of work." - dr inż. Katarzyna Januszewicz

"Thank you very much, for asking me to test the game.

Unfortunately, my friend and I didn't have enough time to play the whole game due to other duties.

From the tested fragment of the game we can draw a conclusion that the game is quite intuitive, but at the same time it requires some knowledge and perceptiveness as well as ability to use all available materials in the rooms. Solving the puzzles is not easy, so it is a kind of challenge. We think that fans of this type of entertainment should not be disappointed.

The only thing I would like to mention is that in the first room it would be useful to have some kind of hint where to get the code to leave the room, e.g. you will receive the code after completing the task or some similar information making it easier/helping you to know what to look for. It was not obvious here. Had it not been for the instructional video with the lecturer, we would not have found out how to find the code to the padlock. We simply picked up on the fact that it had something to do with heating the piece of paper. Not everyone will figure out what to do here in our opinion.

Speaking of codes and the instructional video, there are actual exit codes, which don't work without doing the right things (we checked :)), but they are visible nonetheless.

In the third room there is a directional padlock - is it not worth putting arrows next to it, like in the mazes, to make entering the code easier?

Our observations are made bearing in mind that the recipients of the game will already be students of the last classes of elementary school and while they probably have gaming experience, they often need simple tips on what steps to take in order not to get discouraged.

In my opinion, as one of the commissioners of the group project, your game is a very good example of learning through play. And this goal was 100% achieved by your team. Congratulations on your ingenuity, hard work, and success in getting the job done." - dr Monika Bizewska and mgr Karolina Maciejewska

6. Conclusion

The goal of the project was to create a freely accessible application for teaching various fields of chemistry in a fun way. Tests conducted by the students proved that the application created by them is able to reliably transfer knowledge not only to young people.

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