A Virtual 3D Chemistry Escape Room for Exam Preparations

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Abstract: Chemistry can be incredibly captivating. However, learning the theory can often be challenging and less appealing for students. Providing them with hands-on methods in their learning process is beneficial and also helps to lower the barrier for understanding theory. In a gamified approach, the "ChemScape" virtual 3D chemistry escape room, designed as a realistic laboratory with various equipment and hidden chemical tasks, can help solidify chemical knowledge and prepare students for chemistry exams. In 2023, as part of an e-learning project, the foundation of such a chemistry escape room was established, and several chemical questions were incorporated as escape room tasks. The objective is to discover hidden questions within the laboratory, utilize different instruments (such as scales), conduct virtual chemistry experiments, and solve various chemistry questions using theoretical knowledge (such as nomenclature and understanding of pH) in a game-based setting (utilizing multiple-choice, drag and drop, connecting cables, solving color codes, etc.). Typically, a code (comprising numbers, letters, signs, etc.) needs to be obtained for progression. To solve the chemistry tasks, approximately 10 different door-openers have been developed. Initial user tests have been conducted, and adjustments were made based on the feedback received, which was satisfactory and positive. In 2024, the "ChemScape" escape room will evolve from a game with a fixed set of tasks to a dynamic escape room game with a dynamic database that allows for the creation of new questions at the same stations, significantly expanding learning opportunities. A virtual chemistry laboratory rat provides hints if a participant gets stuck and requires assistance. Furthermore, "ChemScape" will be trialed in chemistry lectures and potentially utilized as an additional attraction at events held at the University of Applied Sciences.

Keywords: Chemistry, Elearning, Exam Preparation, Virtual Laboratory, Escape Game

1. Game-based Learning With Escape Room Games

Gamification methods are often a nice change in teaching, helping to increase attention, to activate participants, and to give easy possibilities to memorize theory, before continuing with the next topic. Especially hands-on methods are very helpful as they activate different senses of the participants at the same time. And, although the designing of escape room tasks is challenging – also outlined by Hermanns et al (2018) - they can often be helpful avoiding boredom and frustration.[1] Together with educational games and simulations, Game Based Learning looks especially promising in higher education [2].

Escape room games are a special kind of gamification. They can be carried out in a physical environment (e.g. a room with different task stations) or in digital forms accessible on a webpage or in an application for mobile devices (e.g. you have to solve different questions in a row connected with links). However, these digital forms are usually known for escape room games with different topics for leisure games but not that much for learning purposes – especially not in scientific or technical fields. Educational escape games are defined as “an educational approach which uses a game format in which students participate in a series of activities designed to acquire knowledge or skills, linked to learning objectives, by solving a series of puzzles in a given period of time” [3].

The general goal of escape room games is to solve different tasks (in a given or variable order) to be able to leave the room, respectively the environment, where the game takes place. Sometimes it could also lead to a treasure.

The Cambridge dictionary has the following definition: “Escape rooms are a game where people are locked into a room and have to find a way to escape by finding clues (= signs or information that help you to find the answer to a problem or mystery) in it, and solving puzzles, or a special room where this is done.”[4]

Escape room games are in some cases designed as one player games but in many cases a group of players solves the challenges together.

2. The “ChemScape”

2.1 The Project

In our study, we aim to introduce "ChemScape" - a virtual 3D escape room game. The project commenced in the first quarter of 2023, and since then, the laboratory room itself and numerous tasks have been developed, rendering the game playable. Various chemical questions have been formulated, encompassing topics such as

the periodic table, chemical calculations, knowledge of chemical formulas and nomenclature, and pH. Over the past months, these questions have been integrated into the escape room tasks.

In the "ChemScape" game, players must discover and solve different chemical questions hidden within the laboratory to progress in the game or complete the final task. Throughout gameplay, a digital clock indicates the remaining time.

The escape room game offers diverse applications. Primarily, it serves as a tool for exam preparation. Additionally, it could be utilized within courses as a form of interim assessment or even as a marketing activity.

2.2 The Purpose and the Advantages

The creation of such a game serves multiple purposes: to enhance students' interest in chemistry, to engage them actively, and to provide them with an innovative tool for exam preparation, all in a gamified and motivating manner. Additionally, short games can facilitate knowledge transfer and improve understanding of chemistry, serving as an effective supplement during lectures to help students stay engaged with course content. "ChemScape" aims to reinforce chemical knowledge, introduce new information, and integrate chemical theory in a novel way, including the safe application of chemical experiments.

Playing the virtual chemistry escape room game is expected to lead to improved performance in chemistry exams and to establish a stronger foundation of knowledge for natural science or engineering courses related to chemistry. Digital escape games offer the advantage of easy setup once programmed, without the risks associated with physical chemistry games or the need for chemical materials, making them a safer and more cost-effective option.

Furthermore, such games can mitigate potential aversion to the subject or its theory, presenting the material in a fresh and engaging format that differs from traditional methods. Generally, gamification is recognized as an effective motivator, capable of transforming seemingly dull topics into enjoyable learning experiences that foster genuine interest and a desire for further exploration.

2.3 The Programming of the Game

For the design of the laboratory, photos of inventory in real chemistry laboratories on the campus of the university have been taken and then designed virtually.

The laboratory and all objects are created with “Unity 3D” (https://unity.com/de). At the moment, the game works as an offline application, in future it will also work as a web-application with a website based on php, html5 and javascript. Questions, tips, equipment, and behaviours of the objects will be inserted in a mysql database via a content management system and can be extracted dynamically depending on the respective exam.

2.4 The Laboratory

The “ChemScape” 3D virtual designed chemistry laboratory contains virtual furniture (mainly laboratory benches, cupboards, fume cupboards, sinks and some safety establishment), equipment as cleaning facilities, analytical instruments (e.g. balances) and a big variety of chemical glass ware and paraphernalia. Figure 1 shows one side of the laboratory room. With the arrows on the right and left side, the player can change the section of the laboratory room.

Figure 1: One side of the “ChemScape” 3D virtual chemistry laboratory room

Some measuring instruments, as for example balances are already designed. Their special feature is that their usage is in a realistic way which means that in the case of the balance you have to use a spatula and see the increasing amount of substance on the rising number at the balance display.

2.5 The Methods

2.5.1 The Tasks

The assignment questions are either present at the virtual laboratory working place or will be shown in the game after solving the previous question. Materials (as e.g. vessels with chemical substances), hints (e.g. a colour code) and useful things (e.g. diagrams, periodic table, ..) are present in the laboratory room – sometimes obvious and sometimes hidden (e.g. behind chemical boxes or in the cupboard). The different chemistry tasks cover theoretical knowledge as well as associated laboratory experiments. Theory from the chemistry lecture gets combined with practical experience from chemistry laboratory work in a game-based e-learning setup.

At the moment around 10 different task stations have been thought of, designed and implemented. To make it more realistic (like in a physical game), when solving tasks, objects and instruments (e.g. scales) have to be used.

Figure 2 shows exemplary one riddle in the laboratory where images can be moved around. For this task, the player finds a sheet of paper in front of the pictures with different solutions. With his chemical knowledge it should be clear, that the solutions in the images in front have to be sorted by increasing pH – meaning from sour over neutral to basic. Without chemical theoretical knowledge, the player might be able to solve this task just with trial and error, but it would not be possible to pass all tasks in a given time.

Figure 2: One task in the "ChemScape" 3D virtual chemistry laboratory

Other tasks in the laboratory already designed concern for example questions to atomic models, elements, nomenclature of inorganic chemical compounds, the gas laws, reaction equations and stoichiometric calculations.

In order to move from one task to the other, different door openers have been developed for this escape room game.

2.5.2 The Door-openers

For solving different kinds of chemistry questions, a variety of door-openers has been designed. They include for example multiple choice, drag and drop, codes (colours, numbers, signs, ..) or n:n-connections. Table 1 gives some examples.

Table 1: Door-openers used in the "ChemScape" 3D virtual chemistry laboratory

Number	Door-opener	Example for Usage
1	bring images into a certain order	line up solutions by increasing pH value
2	type a code into a display	a code made with element symbols
3	select a test tube and put in the right slot	name and chemical sum formula

Number	Door-opener	Example for Usage
4	single-choice slot: select the right option in different slots	only one sum formula is correct
5	weigh a certain amount of a substance on a scale	after a stoichometric calculation
6	bring sliders into the right position	for the oxidation number of an element in different compounds
7	get a certain amount of a liquid with a pipette	after a stoichometric calculation
8	n:n cable-connection for assignment	names of acids and their corresponding salts
9	create a certain amount of gas	after a stoichometric calculation
10	drag & drop different objects into different boxes	sort metals and non-metals

2.5.3 User Tests

First user tests (n = 45) have already been performed and evaluated. The individual participants played the game in groups on mobile devices under supervision. Subsequently, comprehensive qualitative feedback was collected. The test participants were asked to the general idea of such a game for learning chemistry, to the design of the laboratory environment, its usability and the didactic value in comparison with traditional learning materials.

The outcome of this evaluation test showed some minor technical problems or didactical ambiguities. This means that the formulation of some questions was not sufficiently clear and had to be clarified. Furthermore, some buttons to click on were too small and some door-openers did not work on an ipad tablet. Directly after the tests the improvements were made according to these results. The feedback about the game itself and the set-up was satisfying and positive.

As can be inferred from these statements, an empirical combination of interviews and actual gameplay was chosen as the method for game optimization.

3. Outlook

In the current version, the game can be played without any problems. But all questions are connected to one set of solutions. In the upcoming months, a database will be programmed which will open the possibility to change questions at the different task stations and to hereby generate a dynamic game. Although the order of the tasks combined with the different door openers stays the same, the choice of the tasks should be possible in a randomized manner or by a selection of the person setting up the learning environment. The learning possibilities will hereby be expanded enormously. It will also be possible to choose whether experiments or answers can be redone (one time or more times) before the results are finally inserted and checked.

Additionally, if players need hints, a laboratory rat will be present in the room which will be able to help along in the game.

In the following semester, the “ChemScape” escape room game will be tried out in chemistry lectures and maybe as well as additional attraction e.g. at events at the University of Applied Sciences.

References

Hermanns, Deal, Campbell, Hillhouse, Opella, Faigle. (2018). “Using an “escape room” toolbox approach to enhance pharmacology education”, Journal of Nursing Education and Practice, Vol 8, No. 4, pp 89–95.

Crocco, Offenholley, Hernandez. (2016) “A proof-of-concept study of game-based learning in higher education”, Simulat. Gaming, Vol 47, pp. 403-422.

Soares, Barel, Leite, dos Santos, Carlos, de Carvalho, Gianotto-Oliveira, Cecilio-Fernandes. (2023) “Implementation of Escape Room as an Educational Strategy to Strengthen the Practice of Safe Surgery”, Journal of Surgical Education; Vol 80, I 7; pp 907-011.

https://dictionary.cambridge.org/dictionary/english/escape-room