

Finding the Target Solution and its Concentration: A Chemistry Escape Room

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Abstract: Exploring secrets and solving puzzles in a detective-like manner can be highly motivating and engaging. Chemical puzzles offer a suitable framework for such inquiry-based learning experiences. In the work presented here, participants investigate four colourless solutions in a mini escape room that lasts approximately 15–25 minutes. According to the introductory information, one of the four solutions is the target solution and is described as being neutral with respect to pH while exhibiting high electrical conductivity. In addition, participants are asked to determine the concentration of this solution. A pH universal indicator paper and a conductivity meter with a sensor are provided as experimental tools. At first glance, all four numbered solutions appear identical, which requires the participants to proceed systematically. The investigation typically begins with cautious sensory examination. One solution can be excluded immediately due to its strong vinegar-like smell, indicating an acidic character. Further pH measurements allow the exclusion of a basic solution. Finally, conductivity measurements reveal the target solution as electrically conductive while remaining pH-neutral. This first stage already demands organised testing, careful observation, and teamwork. After identifying the correct solution, participants must determine its density. To do so, there are three play versions how to reveal the identity of the solution as aqueous sodium chloride. Entering its molar mass as a three-digit code into a fake dictionary box leads to a densitometer spindle. Following the information at the station, participants perform the density measurement and determine its concentration by using a diagram correlating concentration with density. The result serves as code for a final box containing a small “treasure”. This escape room has been successfully implemented in various educational contexts, including student motivation and team-building seminars, university research nights with mostly families, and workshops at children’s university workshops with participants aged 6–12 years. Feedback has been consistently positive. The activity is perceived as entertaining, accessible, and appropriately challenging, while fostering key competencies such as curiosity, logical reasoning, organised experimentation, and collaborative problem-solving using familiar chemicals.

Keywords: Chemistry, Escape room, Experiments, Density, pH

1. Introduction

1.1 Game-based Learning and Gamification

Game-based learning and gamification are perfect tools for introducing challenge, feedback, progression, problem solving and collaboration into learning environments. In game-based learning, games are used as learning environments or activities. Gamification generally refers to the integration of selected game elements into non-game contexts. The effects of both approaches as means of increasing players' engagement and motivation are highly dependent on the educational context and on how the game elements are integrated into the learning process. Recent research in chemistry education published by Elmali, Freund, and Tiemann in 2026 confirms the growing interest in game-based approaches and specifically examines their potential effects on students' academic achievement, motivation and engagement.[1]

1.2 Escape Room Games

Escape room games are a special kind of gamification. Their main objective is to solve a series of tasks — either in a set or flexible order — to exit the room or environment where the game is held. In some cases, the goal might also be to discover a hidden treasure.

In the Cambridge dictionary, the following definition for escape rooms can be found: “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.”[2]

1.2.1 Educational escape rooms

Educational escape rooms represent a particularly interesting form of game-based learning. Typically, a narrative or mission are combined with a sequence of interconnected challenges. Participants are required to solve problems concerning educational topics, interpret information, communicate with others and make decisions within a limited time. These characteristics create an inherently active learning environment with the potential to support learning through active participation and collaboration. Disciplinary knowledge can become a very valuable tool for problem solving.

According to Veldkamp et al. (2020), teamwork and time constraints are central characteristics of educational escape rooms. Concerning the learning effects, they nevertheless point out that perceived learning does not necessarily correspond to actual learning outcomes. Aligning game elements with educational objectives together with reflection and debriefing are therefore recommended to further strengthen the educational potential of escape rooms.[3]

1.2.2 Chemistry-related escape rooms

Different kinds of chemistry-related escape rooms have been developed for different educational settings and purposes in the last years. For example, among others, a physical escape room about four metals [4], a laboratory-based chemical escape room [5], or a digital educational escape room for secondary chemistry education focusing on selected principles of green chemistry.[6] In all of them, the escape rooms were not merely used as an entertaining wrapper around chemistry questions, but chemical problems were embedded into an escape-room scenario as a structured learning environment, combining chemistry-related tasks with teamwork and an engaging game structure.

A very good systematic overview about methodological approaches to gamification in chemistry teaching for the period 2015 to 2025 gives the work from Peralta Holguín, Quishpe-Solano, and Yunga-Godoy. The results of the 43 studies show that gamification significantly enhances students' motivation, engagement, understanding of chemical concepts, and development of STEM-related skills. Nevertheless, identified limitations are such as the need for teacher training, technological resources, and structured planning.[7]

In the particular case of the presented work, a physical Escape room game for usually participants working in teams is described.

2. The Chemistry Escape Room

2.1 Idea and Motivation

2.1.1 Enhancing the interest for chemistry

Natural sciences such as chemistry are highly fascinating, yet they are often perceived as challenging. To make these subjects more accessible and less intimidating, games can serve as an effective tool. By integrating problem-solving and experiments into a playful, gamified environment, learning becomes more engaging and enjoyable. This approach is particularly effective when the game incorporates substances or topics familiar from everyday life, school, home, or environmental contexts. In such settings, learners often acquire knowledge almost unconsciously and may even develop a deeper interest in exploring the subject further.

Furthermore, education moving beyond the transmission and reproduction of knowledge and instead engaging participants (students, families, even children, ...) in active, collaborative and meaningful learning activities can increase understanding and interest in the field of chemistry and related natural sciences.

2.1.2 The players

The described escape room is designed for students, as well as children, youngsters, adults, and families with a general interest in natural sciences and puzzle-solving. Systematic testing, careful observation, and thoughtful interpretation will be necessary for solving the puzzles. As it is advantageous for the players to have basic knowledge and combination skills in natural sciences and they are allowed to perform analytic testing with chemical vessels (such as beakers, bottles, and measuring cylinders) and instruments (such as a conductivity meter or a densitometer spindle), younger children may require some assistance with handling the instruments, answering certain scientific questions, or reading and interpreting the periodic table or the concentration-density diagram. Nevertheless, they are able to understand and enjoy the game, particularly due to the connections between the used substances (e.g. a saline solution) used and everyday life. Grown-ups and especially students with some background or more general knowledge in natural sciences should be able to complete the escape room without or with only very little help using the information given at the station, their general knowledge and the capacity of drawing conclusions.

Throughout the game, a station supervisor is present to guide the players - providing support where necessary, offering hints, and asking questions to enhance their scientific understanding, maintain motivation and leading them further in the game.

2.1.3 *An escape room safe and easy to implement*

The escape room presented in this paper focuses on a range of chemicals commonly encountered in daily life, and prepared as solutions, such as saline solution (table salt, sodium chloride), vinegar (acetic acid), dissolved baking soda (sodium hydrogen carbonate), and distilled water. These substances are safe to handle and help bridge the gap between scientific experimentation and everyday experience.

On top of that, the compact format of this mini escape room combines selected escape-room mechanics with chemistry-related problem solving within a format that can be implemented with comparatively limited time and resources. It may therefore offer a more feasible way of integrating escape-room elements into regular chemistry teaching in different settings (e.g. lecture, student competition, science activity for families) – in contrast to relatively elaborate implementations of bigger and more complex game settings.

Depending on the age of the players and the overall time available, participants typically need around 15 to 25 minutes to solve the tasks - determining the target solution and its concentration and reveal the final code.

2.2 **Description of the Escape Room**

2.2.1 *Topic and summary*

In this escape room, players must identify a target solution (the “favourite solution of the professor” in the game story) with certain properties concerning pH and electrical conductivity out of four colourless solutions and determine its concentration. The target solution is neutral in terms of pH while exhibiting high electrical conductivity. The solutions are analysed by smell, as well as by measuring their pH and conductivity. Measuring the density of the target solution and subsequently determining its concentration with a concentration-density diagram presented at the escape room station leads the players to the final code.

2.2.2 *Learning objectives*

The main learning objective is to let the participants get in direct touch with chemistry. They should learn about different substances that they might even already know from daily life and on top of that, get experience in chemical work by performing simple chemical tests – starting with smelling but also measuring the pH and the electrical conductivity. The players should observe the experiments attentively, do the testing in a structured and systematic way and draw correct conclusions from the test results necessary for the decision which solution must be excluded, and which remains according to the desired properties of the target solution.

Another learning objective is that participants realize that colourless solutions appearing identical at first glance, as found at the beginning of the game, are not necessarily water and will have different properties (e.g., toxicity, pH, conductivity) — something that may surprise some participants. Their differences can be identified through analytical testing (which also includes smelling).

Another chemical learning objective is that participants learn about the pH (i.e., which substances are acidic, basic, or neutral), electrical conductivity (including its measurement in μS and the reasons why substances conduct electricity), selected chemical elements and their organization in the periodic table, as well as the density of solutions (e.g., 1 g/mL for water), how to measure it with an easy technique, and the relationship of density and concentration. Since, as it will turn out in the game, the target solution is a sodium chloride solution, participants should also recognize that, compared to the density of pure water (1 g/mL), salt solutions have slightly higher densities.

The last objective is that, after having successfully completed the game, participants should have gained knowledge and enhanced interest about chemistry that they can relate to in everyday life — perhaps even whenever they use table salt, vinegar, baking powder or simply water.

2.2.3 *The set-up*

The escape room consists of one table and, if available, two (pin) walls or boards on one table corner for information on posters. If pin walls are not available, it would be good to have other possibilities to put on posters with useful information for the game (e.g. walls). Pin walls or comparable boards are also useful to separate the station from other activities in the room (see Fig. 1).

On the table, the players find four small, numbered bottles containing colourless liquids and, in front of the bottles, four small beakers with corresponding numbers. Furthermore, a sheet with a table and a pen for

recording the analysis results, universal indicator paper strips, tweezers, a conductivity meter, a measuring cylinder, distilled water in a spray bottle, a book (either an “English dictionary” or a book on “Fundamentals of Chemistry”), and a black box with a 3-digit code can be found on the table. Depending on the version to play (see later in more detail), also a cryptex is placed clearly visible on the table.

In addition to the items on the table, posters containing useful information for the game are placed at the station. One poster contains the welcome letter for the players, introducing the game’s goal. Another one shows a description of density measurements using a densitometer. Also, a diagram relating mass concentration (x-axis) to density (y-axis) is provided. Furthermore, the periodic table of chemical elements is available - either on a laptop or as an additional poster. Moreover, a list of chemical compounds is provided, including their German and English names, as well as their chemical formulas. Finally, information on pH measurement using universal indicator paper and the corresponding colour scale (with some examples for chemicals (e.g. acetic acid or mineral water) and their pH) is displayed at the station.

Figure 1 shows the set-up of the escape room in two different configurations.



Figure 1: Set-up of the escape room at two occasions

2.3 Description of the Tasks in Detail

The escape room can be divided into six steps. The first step marks the beginning of the escape room and involves reading the welcome letter, examining the items on the table, and reviewing the information provided on the posters.

The second step involves identifying the target solution with the desired properties: a neutral pH and electrical conductivity. The third step is to determine the composition of the target solution. At this stage, different game variants are possible, which will be described in more detail later.

In steps 4 and 5, the concentration of the target solution is determined. First, the densitometer spindle must be found (step 4). Subsequently, the density of the target solution is measured following the procedure outlined on the poster, and its concentration is determined using the mass concentration–density diagram (step 5).

Finally, step 6 concludes the escape room by requiring the participants to enter the final code.

Figure 2 gives a schematic overview of the six steps of the escape room.

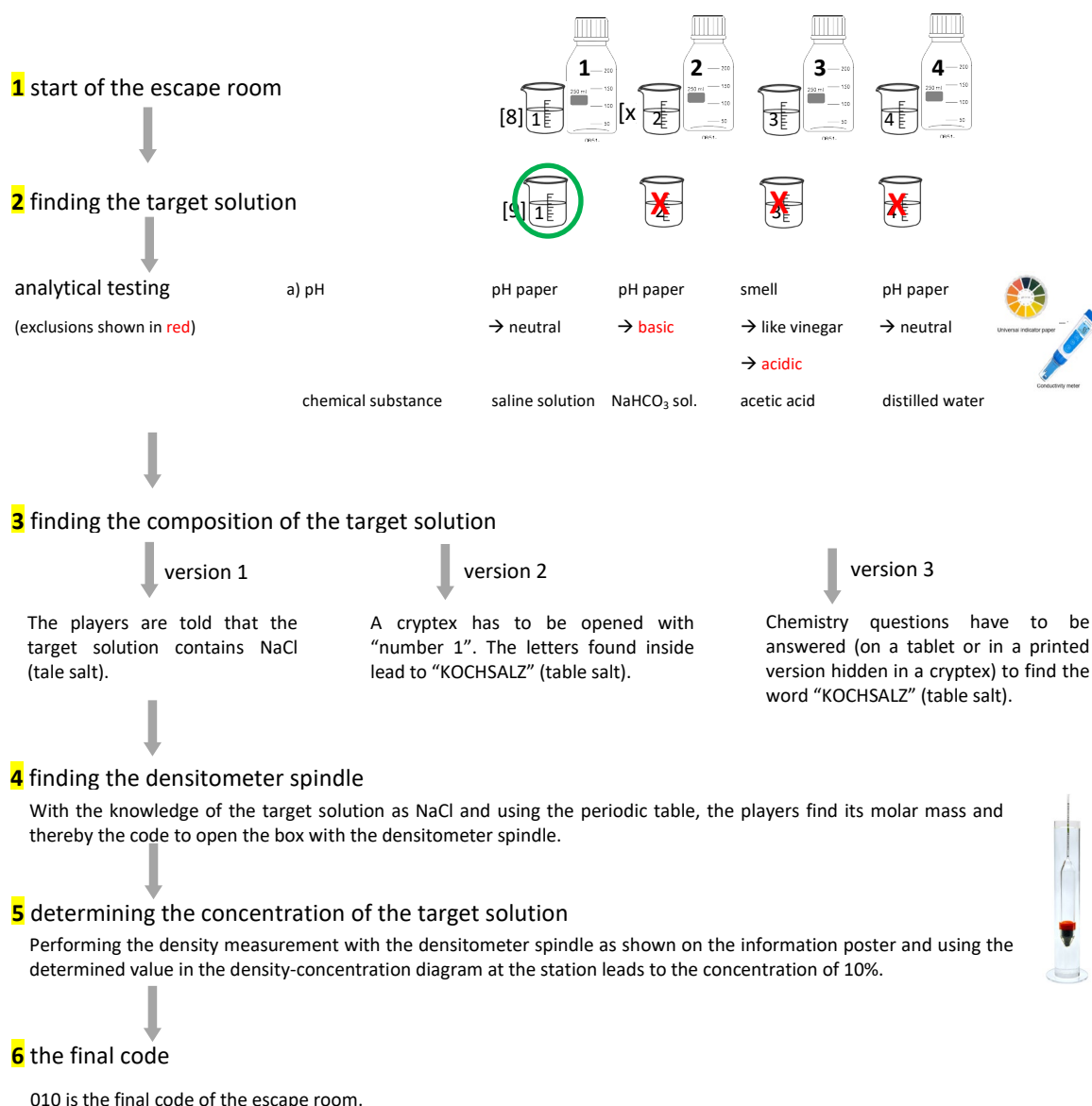


Figure 2: Overview of the six steps to solve the escape room

2.3.1 Start of the escape room

Upon arriving at the escape room station, the players find a poster with the following information:

"Hello. Welcome to my lab. Unfortunately, I am very busy at the moment. I still have to finish this experiment and cannot take my eyes off it.

However, I have prepared a quiz for you on the table. If you identify my favourite solution among the four colourless solutions, as well as its concentration, you can open the treasure box using a code. My favourite solution is pH-neutral and highly electrically conductive. Some measuring instruments are available on the table."

2.3.2 Finding the target solution

When the players begin examining the four solutions, they initially appear identical at first glance: all four numbered solutions on the table are transparent and colourless. Based on the information provided in the introduction, the players know the relevant properties of the target solution in terms of pH and electrical conductivity: the solution should be pH-neutral but electrically conductive.

Before measuring pH and conductivity, the players are instructed by the professor or game assistant to begin with a careful sensory examination. At this stage, one of the solutions can typically be excluded immediately due to its strong vinegar-like smell, whereas the other solutions are odourless. The familiar smell, reminiscent of vinegar used in salad dressings, provides an initial indication of the solution's acidic character.

To test the pH of the remaining solutions using universal indicator paper, a poster (see Fig. 3) provides the corresponding colour scale, along with examples of neutral, acidic, and basic solutions.

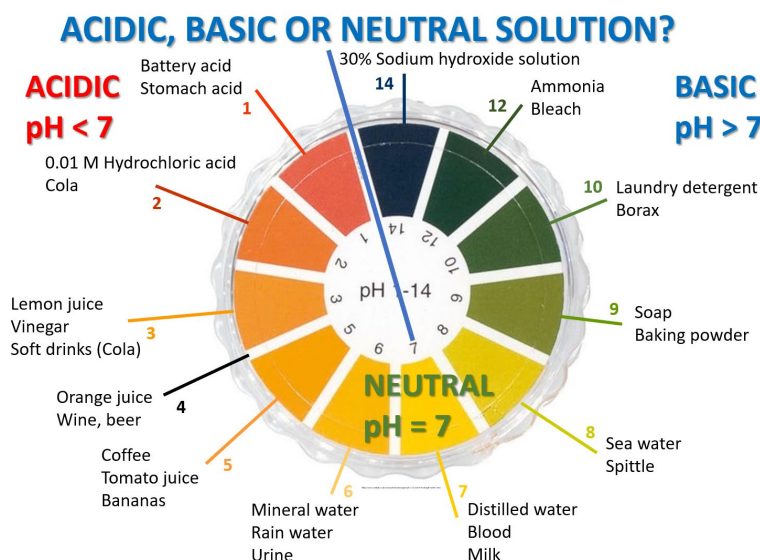


Figure 3: Colour code for the pH testing with universal indicator paper [10, modified by the author]

The test can be performed by holding pieces of indicator paper with tweezers in each solution and observing the resulting colour change. Comparing the resulting colours with the scale provided on the poster allows the players to readily exclude the basic solution, which contains sodium bicarbonate (as the players are informed by the station supervisor), commonly known as a leavening agent used in baking powder. The other two solutions turn out to be neutral, as the indicator paper retains its original colour.

Find the neutral and conductive solution

solution	smell	acidic	pH neutral	basic	conductive
1					
2					
3					
4					

The target solution has the number _____.



Universal indicator paper



Conductivity meter

Figure 4: Worksheet for the solution analysis

After the pH measurement, two solutions — one acidic (No. 3) and one basic (No. 2) — can be excluded, leaving the two colourless solutions, No. 1 and No. 4. Recalling the introduction, the second requirement for the target solution (the professor's favourite) is that it must be electrically conductive.

By placing the conductivity meter in each solution, a clear difference becomes apparent. Solution No. 4 shows no or very low electrical conductivity, as it consists of distilled water containing virtually no dissolved ions, as explained by the game supervisor. In contrast, solution No. 1 reaches a maximum value of approximately 4,000 μS on the digital instrument's measurement scale.

The conductivity measurements therefore identify solution No. 1 as the target solution, as it is highly electrically conductive while remaining pH neutral.

2.3.3 Finding the composition of the target solution

Depending on the planned maximum duration of the escape room, different game variations can be used at this stage to determine the composition of the target solution.

In Version 1 — the fastest version of the escape game — the professor directly informs the players that her "favourite" solution is an aqueous sodium chloride solution, commonly known as table salt in everyday life.

In the slightly longer Version 2, a cryptex can be found on the table. To open it, the players must enter the correct beaker number, "1", corresponding to the target solution they have identified. Inside the cryptex, they find letter tiles (see solution in Fig. 5) that, when arranged in the correct order, spell the German word for table salt, "KOCHSALZ". This reveals the identity of the target solution as an aqueous sodium chloride solution.



Figure 5: Tiles in the cryptex that correctly put together spell the word "KOCHSALZ" (table salt)

In the longest version (Version 3), the participants, who may have slightly more prior knowledge of chemistry, find a tablet displaying an open questionnaire. Alternatively, a printed version of the questionnaire can be hidden inside a cryptex, which can be opened by entering the correct beaker number, "1". The questionnaire contains questions about chemical elements from the periodic table (see Table 2).

To answer the questions, the participants can use the periodic table provided in the escape room or draw on their existing knowledge of chemistry. They are also allowed to look up the answers on the internet.

Table 1: Questionnaire to determine the right letters for the composition of the target solution

element	question	letter
potassium	A metal with one outer (valence) electron that often reacts very vigorously with many other elements and compounds; found in bananas.	K
oxygen	A life-essential diatomic element in the atmosphere.	O
carbon	On the Mohs hardness scale, depending on its modification, the softest and hardest element (Mohs hardness 0.5 and 10).	C
hydrogen	Together with oxygen, these two elements form water.	H
sulfur	The element of one of the strongest and most corrosive acids, formerly known as "oil of vitriol."	S
aluminium	The silvery-white light metal is the most abundant metal in the Earth's crust.	AL
zinc	Main alloying element of brass besides copper; in its chemical symbol, the second letter of the chemical symbol is omitted.	Z

So, the solution to the composition of the target solution is "KOCHSALZ".

A list of chemical compounds given with German and English designations as well as their chemical names and sum formulas (see Table 2) then leads the players to the sum formula of table salt.

Table 2: Chemical compounds with German and English designations and their chemical names and sum formulas

salt	Chemical designation	English	German
NaCl	sodium chloride	table salt	Kochsalz
NaHCO ₃	sodium bicarbonate	baking powder	Backpulver
CH ₃ COOH	acetic acid	vinegar	Essig
NaCl	sodium chloride	table salt	Kochsalz
H ₂ O	water	water	Wasser

2.3.4 Finding the densitometer spindle

Recalling the welcome letter, after identifying the target solution and its composition (sodium chloride), the participants must determine its density to then use the concentration-density-diagram on the poster to determine the concentration of the solution. A poster provides instructions on how to measure density using a densitometer spindle. Finding this instrument is therefore the next objective.

As they look around the escape room station, the participants notice several objects that they have not yet used and that are presumably needed to solve the next part of the game. In addition to a measuring cylinder, there is a book on the table — either an “English Dictionary” or a book on the “Fundamentals of Chemistry”. When the participants open the book, they discover that, instead of containing pages, it conceals a box with a three-digit code inside and pictures above it.

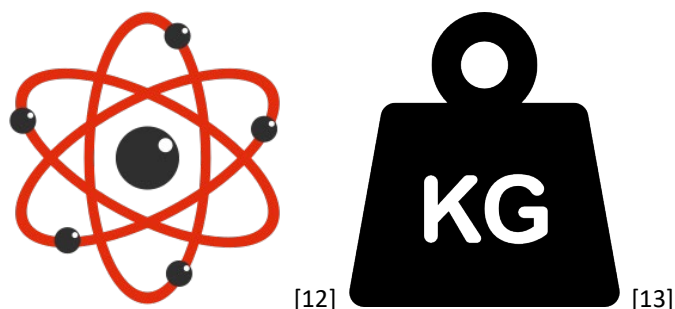


Figure 6: Signs above the 3-digit code in the book safe

By applying combinational reasoning, the participants can identify the image on the left as an atomic model and the image on the right as a weight, leading them to the correct combination, “atomic weight”. They can therefore infer that the atomic masses of the elements present in the compound dissolved in the target solution are required.

Referring to Table 2, which lists several chemical compounds, the participants search for the compound corresponding to the target solution and identify the chemical formula of table salt (sodium chloride) as NaCl. By looking up the atomic masses of Na and Cl in the periodic table and adding them together, they obtain a molar mass of approximately 58.5 g/mol.

Entering the calculated molar mass as a three-digit code into the fake dictionary or chemistry book reveals a densitometer spindle.

If the escape room is used in an educational setting, the professor or station supervisor can then ask the participants whether they know the density of water. If necessary, they can explain that a density of 1 g/mL means that one litre of water has a mass of approximately 1 kg. This provides an additional connection to everyday life and can help participants develop an intuitive understanding of the relationship between density, volume, and mass — for example, when estimating the weight of aqueous liquids while shopping at a supermarket.

The participants are then asked to predict whether the density of water will increase, decrease, or remain unchanged when sodium chloride is added. When prompted in this way, most participants are expected to predict an increase in density, providing an opportunity to reinforce the concept that salt water has a slightly higher density than pure water.

2.3.5 Determining of the concentration of the target solution

Following the instructions provided at the station, the participants now measure the density of the target solution by carefully placing the densitometer spindle into the measuring cylinder containing the sodium chloride solution (see Fig. 7). The density can then be read directly from the scale at the point where it intersects the surface of the liquid.



Figure 7: Density determination with a densitometer spindle

At this stage, the professor or game supervisor may also explain the measurement principle underlying the densitometer spindle, which is based on Archimedes' principle. This provides an opportunity to connect the game-based task with everyday-life knowledge and to introduce the physical principle underlying the measurement. After correctly reading and interpreting the scale, the participants determine a density of approximately 1.070 g/mL.

To determine the concentration of the solution, the participants use a diagram showing the relationship between concentration and density (see Fig. 8). Starting from the density value on the y-axis, they move horizontally to the regression line and then vertically down to the corresponding concentration value on the x-axis. The concentration of the sodium chloride solution is determined to be 10%.



Figure 8: Diagram for density and concentration of sodium chloride solutions. Left as they find it, right how to read the result

2.3.6 Final code

The mass concentration of the sodium chloride solution serves as code for the final box. In there, the participants find a small “treasure” (e.g. sweets).

2.4 User Tests and Feedback

This escape room has already been used on various occasions at the University of Applied Sciences Upper Austria. For example, it has been featured several times as one of several escape room stations covering topics in the natural sciences and technology at the “Lange Nacht der Forschung” (Long Night of Research). During this event, research institutions remain open until late at night to welcome visitors, often including families with children of different ages. Large numbers of participant groups attended the event, all highly curious about the tasks and motivated to engage with the game.

On other occasions, the escape room has been used for visiting school classes as part of guided tours, as well as for team-building activities at the beginning of an international summer school. Furthermore, the escape room station has also been implemented in chemistry workshops as part of the “KinderUni” (Children’s University).

Participants across all these occasions included children, teenagers, students, and adults of different ages and with varying levels of prior knowledge of chemistry. The feedback was consistently very positive. Participants described the duration of the escape room as appropriate, being neither too long nor too short, and considered the activities scientifically sound without being overly complex. The topics were also perceived as interesting and engaging. The participants’ motivation was clearly observable, even late at night. Solving puzzles in a playful and engaging manner was perceived as enjoyable by participants of all ages!

3. Outlook

As the conception and design of educational games and chemistry puzzles is my passion, I will certainly continue working on similar projects in the future. My ongoing goal is to convey knowledge to others with enthusiasm and enjoyment, using a well-structured and gamified approach.

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