

AN ESCAPE ROOM ACTIVITY IN ANALYTICAL CHEMISTRY

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Abstract

This proposal outlines an escape room activity that integrates key concepts from courses offered by the Department of Analytical Chemistry at the University of Valencia. Designed as an interactive learning experience, the activity encourages students to develop hypotheses, ask questions, and make decisions based on clues and experimental results obtained through analytical instrumentation. By engaging in this hands-on approach, students can apply the theoretical knowledge gained during their academic studies. Escape room-style activities are rooted in active learning, placing students at the center of the experience while fostering the development of theoretical, practical, and behavioral skills. Research supports their effectiveness in complementing traditional teaching methods, aiding exam preparation, and enhancing laboratory practice. Additionally, these activities boost student motivation through engaging challenges and promote teamwork in problem-solving scenarios. In this case, the proposed escape room takes place in a laboratory setting designed to simulate the workspace of a missing scientist. Students must complete a series of analytical tests to progress toward their ultimate goal: retrieving a code to unlock the scientist's laptop and uncover the mystery behind their disappearance. The challenges include fluorescence spectroscopy for analyzing tonic drinks, infrared spectroscopy for organic substance identification, and X-ray fluorescence for examining inorganic salts. Each test provides analytical results that lead to the next stage, ultimately guiding students toward the final solution. This initiative makes use of the available facilities and resources at the University of Valencia's Faculty of Chemistry. The required equipment and materials are readily accessible and easily adaptable. The activity is tailored for laboratory courses with an instrumental focus, such as the Analytical Chemistry II Laboratory and the Applied Instrumental Analysis Laboratory, typically taken in the third and fourth years of the Chemistry Degree program.

Keywords: *Analytical chemistry, escape room, instrumental analysis, laboratory modules, undergraduate students.*

1. Introduction

Escape rooms are usually ludic activities that consist of a series of puzzles to be solved in a logical sequence to finally reach a point of conclusion. These have gained interest not only as leisure activities, but also in educational research, with multiple examples having been published in the literature.

Among the most interesting advantages of escape rooms in education, the literature shows that it helps promote critical thinking and increases motivation among students (Veldkamp et al., 2020). Additionally, escape rooms are closely related to Active Learning, a perspective of education that focuses on the participation of students in their learning process, becoming the main character, instead of passive information recipients. As escape rooms make students interact with different items and objects, students are forced to participate in the process and make evidence-based decisions (Zhang et al., 2018).

More specifically, in the field of Chemistry Education, escape rooms can help settle on the theoretical content often taught in theoretical lessons to specific practical cases to be solved. This is especially interesting as experimental and laboratory teaching is a key part of the Chemistry syllabus, so Escape Rooms applied to the laboratory can become an innovative approach to innovate and face students with problems that need to be solved by them using their Chemistry theoretical and practical knowledge.

2. Activity description

2.1. Educational context

This activity has been designed for the module “Applied Instrumental Analysis Laboratory”, a fourth-year subject in the Degree of Chemistry at the University. This context is especially relevant as it allows one to have a grasp on the expected *a priori* knowledge that students are supposed to have at this point. In this regard, at this point of their studies, students have already gone through all the compulsory theory modules, so they should be proficient in describing the theoretical foundations of analytical instruments. Also, given their stage within the degree syllabus, they have gone through several laboratory modules (not only focused on Analytical Chemistry, but also in other areas of Chemistry), so their performance in the laboratory is expected to be independent and adequate.

Finally, it must be considered that this module has been designed for an optional subject, which should mean that students are more motivated towards it as they have chosen it themselves.

2.2. Activity

The activity consists of three different tests, which are planned sequentially, so that solving one of them would path the way to undertake the next one. Each one of these tests or challenges applies a different analytical technique. The idea is that students find some prompts or hints that they should integrate along with their prior knowledge to carry out analytical measurements and, subsequently, analyze the results.

The activity should be carried out in small groups, between two or three students, as it is intended that all of them actively participate in solving the challenges. Bigger groups could end up with a leader who rules and some students who lean on them with minimal to no participation whatsoever. When it comes to time investment, the whole practice is set up to last around two or three hours, as the laboratory sessions of this module are three and a half hours.

Challenge number one is based on fluorescence analysis, and it is the starting point of the whole activity. First, students are presented with some basic instructions indicating that they will find in the lab some objects, instruments (which should be already on to help them spot them), two locked boxes, and a blocked laptop that needs a password to unlock. Next to those instructions, students will find a tonic beverage bottle and a cup with liquid in it. All this material will be placed close to a spectrofluorometer, so students are expected to read the instructions first and start finding out their way through the activity. The logical first step is to spot that the bottle contains tonic, and the label indicates that there is quinine present in it. Thus, based on their prior knowledge and the information at their disposal, students are expected to measure an aliquot of the liquid in the spectrofluorometer.

They will be able to obtain the excitation spectra first, and this could lead them to a first potential result: the excitation maximum of quinine. They might try this value in the first locked box, with no result. Then, they are expected to measure the liquid to obtain the emission spectra, spot the wavelength of maximum emission, and try again in the box. Now, introducing the value of 450 nm will open the box that will take them to the next challenge.

When they open the first box, they will find four labelled tubes containing known organic substances, and a fifth tube labelled as “unknown sample”. Also, some instructions as to how to use an FTIR spectrometer will be included. Thus, at this point, students are expected to join the dots and interpret that the unknown substance must be one of the compounds present in the standards, and that upon their IR measurement, they will be able to stop which one is it. Hence, after having measured all five solids in the instrument, they will have the spectra of four standard compounds and a sample. A visual inspection of all five spectra will lead to the spot which substance is contained in the unknown sample vial. In order to open the next box, they will need to introduce the subindexes of the molecular formula of the unknown compound. For example, if they find that the spectrum of the sample is the same as the tartaric acid standard (whose molecular formula is $C_4H_6O_6$), they will need to introduce 466 in the second locked box to open it. In Figure 1, the set up for challenge 2.

Figure 1. Challenge number 2: Standard and sample tubes within the first box, being measured in the FTIR instrument. The obtained spectra for the sample is compared with the reference spectra.



If they are able to thrive through challenge number 2, they will be able to gain access to the second and last locked box. This one also contains some other tubes with different solids in them. However, in this case, these are inorganic solids. As was the case before, they will find some instructions about the portable X-ray fluorescence spectrometer and (**important!**) some safety instructions that must be followed.

These solids are different inorganic salts with only one metallic element, and they will be contained in tubes labelled as “1”, “2”, “3” ... For example, FeCl_3 , MnCl_2 , CoCl_3 ... can be chosen. It is positive if the different compounds present different colors, as students are always attracted to visually eye-catching substances. The rationale behind this challenge is that students measure the samples in the indicated order (first, substance contained in tube “1”; second, substance contained in tube “2” ...), and the instrument will provide them with a list of the elements present in each solid. At the top of the list, they will have the most abundant element of each salt (this is why it is important that these are simple salts, to avoid potential confusions). Students will need to take note of which element is the most important one in each tube, as their concatenation will be the passcode to unlock the final laptop. In this way, for instance, if tube “1” has Mn as the main element, tube “2” has Fe, “3” has Cu, and “4” has Co, the final password will be “MnFeCuCo”. All this is shown in Figure 2.

Figure 2. Challenge number 3: tubes with different salts in them are measured by the portable X-ray fluorescence spectrometer, and the concentration of main metals is shown in the screen.



It is crucial that this challenge is carried out under close surveillance of the laboratory instructor, as the portable X-ray fluorescence spectrometer emits ionizing radiation. Hence, some safety precautions must be followed:

- The potential leakage of radiation must be controlled by the presence of a dosimeter close to the instrument.
- The samples must be measured using the instrument's protective cover, ensuring that no radiation leaves the measuring apparatus.
- Students must keep a distance from the instrument while it is measuring, at least one meter is advised.

Finally, to bring the activity to an end, once students have unlocked the laptop with the password, they will be presented with a spreadsheet to include their personal information and results obtained.

3. Conclusions and future perspectives

The activity presented in this contribution is a new escape room designed for a laboratory module within the degree of Chemistry at the University of Valencia. This activity makes use of three different analytical instruments as examples for students to be faced with different challenges that they will need to address. The challenges have been designed so that the solution of one of them leads to the start of the next one, in a logical sequence that guides them through the whole activity.

The main objective of this activity is to present an innovative idea to be implemented in instrumental analysis laboratories. In general, laboratory modules are taught in a very routinary manner, usually consisting of a practice preparation, laboratory experimentation, and data analysis. This process, most probably legit and adequate, can also benefit from eventual innovative practices like the one presented here. In this way, we intend to motivate students to be more involved in the practice, as they usually value positively some different methodologies that leave the usual path.

As briefly described in the introduction, educational escape rooms have proven themselves as efficient teaching tools as they promote transversal skills, and not only theoretical knowledge. For example, for the case presented here, students combine different aspects to thrive and succeed in the activity:

- They require prior theoretical knowledge. For example, they need to know that quinine is a fluorescent molecule, the differences between excitation and emission spectra, how to use IR spectra to identify substance...
- They require to have practical skills in the laboratory. In this activity, they do not receive assistance from the laboratory instructor (unless strictly necessary), so they need to work independently to apply the analytical instrumentation.
- They need to work collaboratively in small groups, working transversal skills like team work or communication. This kind of activity promotes more fluent communication, as they are not so used to working in the lab in this way.

Regarding the evaluation of the activity, it is recommended that the laboratory instructor focuses more on the experimental aspects while students are carrying out the challenges. For example, a rubric would be an appropriate tool to guide the observance process. In this rubric, instructors should focus on aspects like skill when using instrumentation, reasoning processes to extract and interpret analytical data, lateral thinking to link that analytical information with the elements of the escape room, or active participation and involvement in the group.

Finally, this escape room is presented as a potential starting point for other instructors willing to innovate in their laboratory teaching. We have adapted it to our facilities and instrumentation, but other analytical techniques and/or solids can be included, sophisticating or simplifying the activity according to the necessities of each particular case.

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