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The Thalidomide Mystery: A Digital Escape Room using Genially and WhatsApp for High School Students

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The Thalidomide Mystery: A Digital Escape Room using Genially and WhatsApp for High School Students

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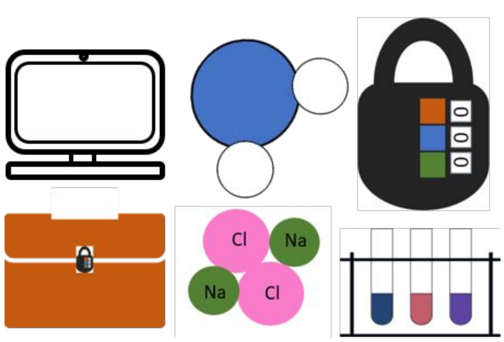
ABSTRACT

This paper reports the development of a digital escape room for high school students using Genially, a web-based media platform. The escape room was used for aid understanding of basic concepts in chemistry and mostly enhance students' classes participation during the COVID-19 pandemic. The activity entitled "The thalidomide mystery" covered the concepts of chemical bonding, pH, acid and base and laboratory glassware. The narrative of the game revolves around the drug named thalidomide; this drug was developed in the 1960s and its use caused several cases of phocomelia. WhatsApp chat groups were formed in order to stimulate an active engagement of the participants and maintain a collaborative and cooperative learning experience among them. Students were required to solve four chemistry puzzles in order to obtain the final password to reach the end of the game. The results obtained showed that the game was very useful for students mainly because it presented an innovative way of teaching chemistry which is different from the traditional way in which the students are usually taught in their classrooms. The game helped the students to review the contents covered and was able to stimulate the active participation of both the students who like to study chemistry and those who do not.

GRAPHICAL ABSTRACT



KEYWORDS

High School / Introductory Chemistry, Collaborative/Cooperative Learning, Humor/Puzzles/Games, Computer-Based Learning, Distance Learning / Self-Instruction, Problem Solving/Decision Making, Acids / Bases, Public Understanding / Outreach.

INTRODUCTION

The importance of maintaining social distancing as a strategy for tackling the COVID-19 pandemic has prompted the need to find new ways to perform activities remotely. With regard to high school students, it is essentially important to devise new activities that can effectively stimulate the active engagement of the students and help boost their autonomy. Pedagogical online games with chemical concepts can be a learning activity that improve students' performance, in terms of engagement and motivation. Chemistry crossword puzzles[1], ChemDraw (drawing molecules software) online activity[2], and escape rooms are some examples of chemistry activities developed to reduce the teaching and learning difficulties caused by the COVID-19 pandemic. Educational games, depending on their format, are mostly considered a way to promote the active and cooperative learning approach, and it is a way to motivate and maintain the attention of students[33]. Group work performing collaborative learning can improve students' attitude towards chemistry, as collaboration brings positive perceptions of this experience to the students[4].

Recent studies reported in the literature have shown that escape rooms are suitable educational activities that can help stimulate cooperative and autonomous learning of participants, apart from boosting their communication and interaction[5].

An escape room is an immersive action game. The activity takes place in teams, and the participants are given a fixed period of time (usually one hour) to discover clues and puzzles and complete tasks which will allow them to normally escape from a locked room[6]. In some rooms of the genre, an escape is not even necessary, because the game can entirely be devoted toward the acquisition of an experience or the successful completion of a puzzle challenge. The generally accepted terminology for this kind of game is "escape room". Escape rooms are often designed under a theme to guide the dynamics of the activity. Usually, the activity takes place in a physical environment, but digital educational escape rooms have also become increasingly popular and are considered a new way of acquiring knowledge and improving remote learning[5]. This type of activity requires initiative, communication, teamwork, critical thinking, attention to detail and logical reasoning skills to be able to apply knowledge under time pressure. Also, can promote collaboration and creativity[7,8]. Successful teams are those owned by participants with a diversity of experience, skills and knowledge[9].

A number of studies published in this journal have employed physical and digital chemistry escape room activities as a way of boosting the students' learning experience [10-23], but none of these studies have used Genially as a tool for the design of these activities. Most of these studies reported to have developed a digital escape room using Google forms. Although Google forms is a suitable tool for designing digital escape rooms, its interactive functions have some underlying limitations. When it comes to the design of escape rooms, one of the major limitations of the interactive functions of Google forms is the absence of functions such as drag-and-drop and hotspots[18]. Genially is a commercial online software with a free option for creating interactive content, which can be used for many different purposes; this tool has great free features, including dials, hotspots, roll-over, sliders, and text entry, to name a few. Also, Genially is easily operated, so it is highly convenient to use even for educators who have difficulty using technological applications. Genially can be used easily on a smartphone or a computer, and the entire game is played on one tab only. This is quite different from playing the game on Google forms in the sense that if one wants to add more elements to the game on Google forms, additional tabs will have to be opened, and this makes the game dynamic a bit unwieldy, mainly on smartphone. In order to ensure the students' cooperative participation in the activity, WhatsApp groups were formed for the execution of the digital game. WhatsApp is a free multiplatform instant messaging and voice calling app for smartphones. Also, users can send images, videos and PDF documents, and make free calls through an internet connection. It is worth noting that none of the previous studies on digital escape rooms published in this journal[10-23] used WhatsApp groups to stimulate a cooperative and collaborative engagement of the participants; this is thus one of the novel contributions of the present study.

This paper describes the development of a digital educational escape room for high school students using Genially and WhatsApp. It is worth noting that this activity was developed for students who do not have a computer or easily access to videoconferencing. The students who participated in the study had basic smartphones that were employed as study tools for the improvement of their learning experience during the COVID-19 pandemic.

The objective of this activity was to aid understanding of concepts of chemical bonding, pH, acid and base and laboratory glassware in chemistry and mostly enhance students' classes participation during the COVID-19 pandemic. The perceptions of the students who participated in the digital escape room are also discussed in this work.

DIGITAL ESCAPE ROOM DESIGN AND GAMEPLAY

The activity was based on elements of the model created by Nicholson[24] to develop an escape room. A genre, configuration, narrative, chronology and challenges for the activity were defined:

- Genre: Mystery
- Setup: Chemistry Laboratory
- Narrative: the thalidomide mystery
- Chronology: Present
- Challenges: Each box in Figure 1 corresponds to a chemistry concept in Figure 2 (i.e., the purple box corresponds to the chemistry concept in the purple circle – laboratory glassware).

Gameplay/Execution of the Game

This activity was developed to engage and help understanding some basic concepts of general chemistry. Groups of 5 and 6 students must be formed on WhatsApp to aid communication between them during the execution of the game. The students are allowed to ask for tips (see the Supporting Information) to a room master (usually, the class teacher) present in the WhatsApp chat group if they got stuck in a puzzle. WhatsApp environment is also used by students to exchange information, ideas and tips between them. Therefore, working as a team, the WhatsApp groups have 45 minutes to successfully solve the puzzles together in order to "get out of the room". It's not supposed to have any competition between the groups. This activity can also be applied in a face-to-face class, in groups of up to 3 students using the same device. In this case, there is no need to WhatsApp groups, because they are in-person groups. Before starting the game, it is necessary to show a video with the game instructions (the video is available on Supporting Information).

Game Description

In the commencement of the game, an introductory video is presented; this video allows the students to get immersed in the narrative of the game. The video presents a brief history of thalidomide in the 1960s. During the presentation of the video, the following message appears on the screen as though someone was invading the connection: you are a scientist trapped in a room, and to get out of it, you will need to understand the relationship between thalidomide and the cases of phocomelia that resulted from the use of this drug by pregnant women.

At the end of the introductory video, students proceed to a room with four boxes and a computer (Figure 1).

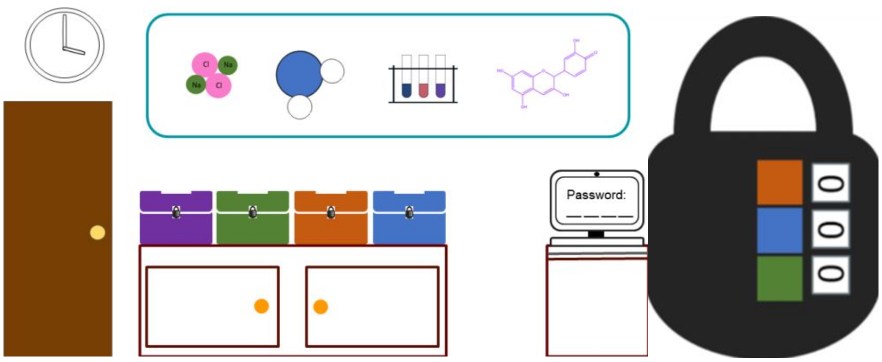


Figure 1.First room in the digital escape environment (left) and the three numeric padlocks with colored squares (right).

Description of the Puzzles in the Escape Room

The escape room has four puzzles, and the students are required to solve all the puzzles in order to obtain the final password that leads them to the end of the game. Each of the four activities (puzzles) consists of a box with a numeric padlock of three numbers that are linked to colored squares (Figure 1). When the students open a box, they receive a clue to the history of thalidomide. The clue is not directly related to the concept of chemistry worked in the puzzle; it is just a clue for the student to better understand the final video of the game.

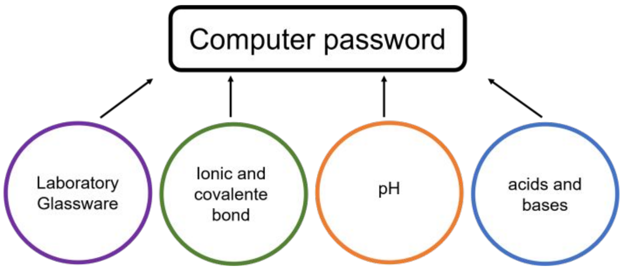


Figure 2. An open structure scheme related to the challenges that need to be completed in the digital escape room (the scheme was adapted from the work published by Nicholson[3]).

Purple box. This puzzle is intended to review the terminological meaning and function of Erlenmeyer, round-bottomed balloon and beaker. Some laboratory glassware can be found distributed around the scene (Figure 3). When one clicks an item, a card appears with a colored square relative to the number of the padlock and a description of the function of the object. Also in the scene, there is a hidden tip that shows that the amount of glassware is the code of the lock. The student must count the amount of Erlenmeyer, round-bottomed balloon and beaker in the scene in order to solve the puzzle. After opening the box, the student discovers the first number of the final password and an information card which states that the thalidomide molecule has two enantiomers and explains the structural difference between them (Figure 3).

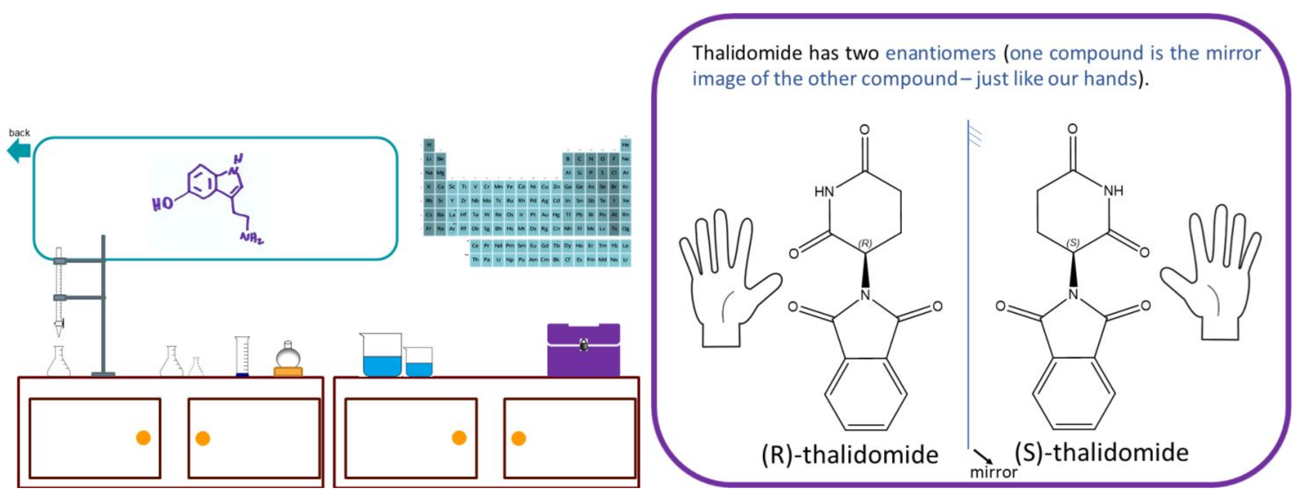


Figure 3. The purple box scene (left) and the purple box card (right).

Green box. This puzzle refers to the difference between an ionic bond and a covalent bond. The puzzle relates ionic bond to the NaCl ionic crystal lattice and cooking salt and associates the covalent bond with a water molecule and water in a cup. In the scene, one can observe the presence of objects and images illustrating both ionic and covalent bonds with colored numbers on the side. Hidden in the room, there is a text linking the objects and images. The student needs to match all items in order to open the green box. The puzzle can be solved in different ways, and depending on the way the students decide to solve the puzzle, they are required to link the concept to its corresponding example. After opening the box, the student discovers the second number of the final password and an information card that shows the following: thalidomide molecular formula, structure and bond types. (Figure 4).

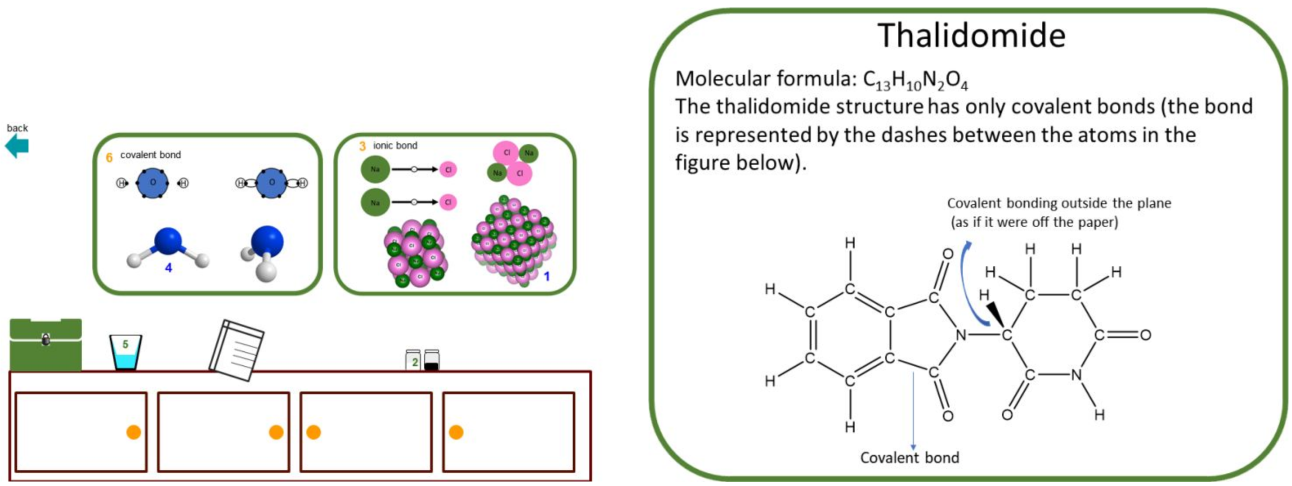


Figure 4. The green box scene (left) and the green box card (right).

Orange box. This puzzle focuses on the color-changing property of anthocyanins - present in red cabbage, when in contact with other substances of different pH. In the scene (Figure 5), one will see a pH scale with colors representing the function of red cabbage as a pH indicator and a chart showing the pH of lemon juice, tap water and anti-acid tablet solution. One will also see a stand which consists of three test tubes with colored substances (dark blue, pink and purple) and a computer with an idea light bulb. When the student clicks on the computer, the screen will show an experiment performed with red cabbage extract and three substances (which are the same as shown on the whiteboard). In the scene, there is also a written tip which shows that the pH of the substance corresponds to the lock password. To discover the password of the lock, the student must match the substances on the board with the substances on the stand and their respective pH. After opening the box, the student discovers the third number of the final password and an information card which shows that the two enantiomers of thalidomide can both exist and be transformed into one another at the human body pH (Figure 5).

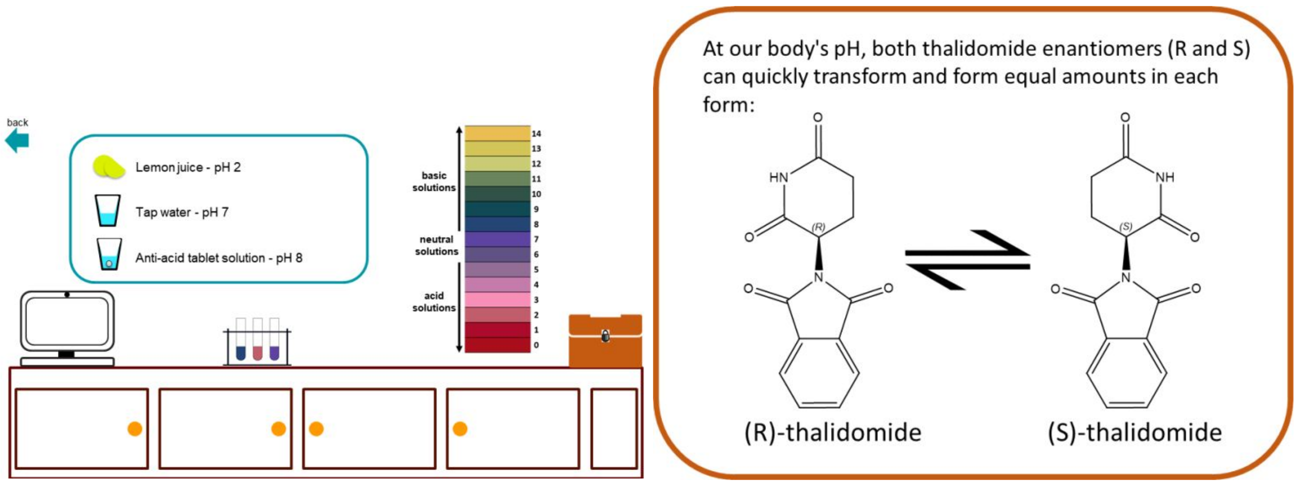


Figure 5. The orange box scene (left) and the orange box card (right).

Blue box. This puzzle describes the difference between ionization and dissociation, and between the ionization of a weak acid and a strong acid, as well as the dissociation of a strong base and the difference between the size of atoms in covalent and ionic bonds. In the scene, there are three beakers with three substances: HF, HBr and NaOH. The student is required to find out the beaker that contains the following: the strong acid (HBr); the weak acid (HF); and the strong base (NaOH). A hint is provided in the scene to help the student find the information. There are also two hidden cards in the scene that are complementary to one another. One card contains a code and the other card contains the caption that corresponds to the code; the student is required to interpret these cards. Thereafter, the student needs to count the following in order to discover the password of the lock: i) the amount of unionized weak acid molecules and weak acid ions; ii) the number of unionized molecules of strong acid and ions of strong acid; iii) the amount of strong base and undissociated base ions. After opening the box, the student discovers the fourth and last number of the final password and an information card which presents pictograms of thalidomide and shows that it is a toxic substance that is hazardous to human health (Figure 6).

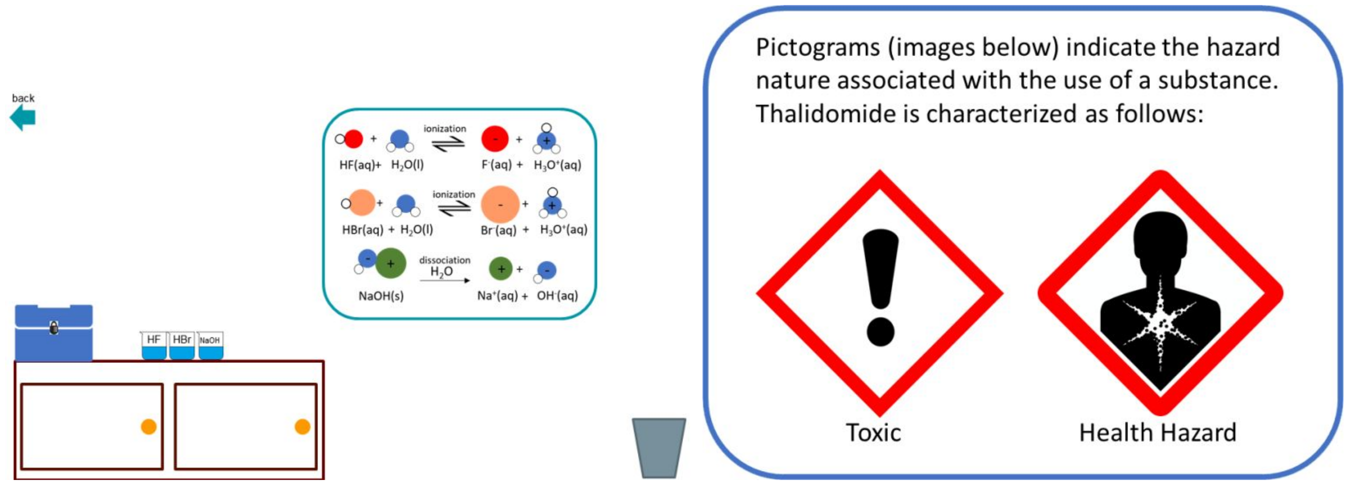


Figure 6. The blue box scene (left) and the blue box card (right).

At the end of the game, the player has a 4-digit password. By entering this password into the computer of the first scene (Figure 1), an explanatory video can be watched, in order to give a chemical explanation to the student of the question proposed in the opening video: what is the relationship between thalidomide and the cases of phocomelia that resulted from the use of this drug by pregnant women? After that, the game is over.

Link to the game and box codes are available in the Supporting Information.

Boxes sequence

The purple box puzzle was developed by the authors to be the first and easiest box to be resolved, so students can solve it to understand how the game works. Then, the boxes were placed in easy-medium-easy-difficult level order considered by the authors for high school students. They can opt to start from any box, what give them choice option. But this order was established to obtain activity with an optimal challenge level. That is, the activity challenges must interact and correspond to the perceived abilities of the person performing the task to avoid a very high level of anxiety or apathy felt by the student if the challenge exceed abilities or requires low skill, respectively [25]. The chemical concepts covered in the puzzles are basic level. Considering a classroom is heterogeneous as there are students with more and less difficulty in chemistry, what makes the box easy or difficult is the logical reasoning that is required to solve it. The chemical concepts in the narrative are just illustrative, this strategy was used to not confuse the student with an excessive quantity of chemistry concepts.

EVALUATION AND DISCUSSION

The game was played by a hundred students from different states and schools in Brazil. The groups were formed with 4 to 6 students, totaling twenty groups. Of these groups, only 3 were unable to complete the activity because class time was over. Nine groups completed the activity within the stipulated time limit (45 minutes); five groups completed it within 45 to one hour; three groups completed it after one hour. Seven groups asked for additional tips during the game. At the end of the game, the students were asked to voluntarily answer a feedback questionnaire. The items in the questionnaire were if they had already participated in an escape room game, if they managed to escape from the room, how much time was left, how many members were in the group, if any activity was very difficult and very easy and which one, what did they learn during the game and they were asked to write in just one word the experience in the game.

Of the hundred students that took part in the research, 48 responded to the questionnaire anonymously through Google forms. Overall, the activity had positive feedback. Thirty-nine students reported to have never participated in an escape room (both physical and digital), while nine have already participated. Figure 7 illustrates the word cloud obtained from the one word that described the students' experience with the digital escape room. From 48 words, only two described negative feedback: medium and horrible.

Figure 7. Word cloud of answers for item: type only one word to describe your experience (n=48).

With regard to the difficulty of the tasks in the boxes, in an open ended-question, 23 students responded (Figure 8) the tasks in the blue box were the most difficult; 7 considered all the puzzles difficult; 8 considered none of them difficult; 5 considered the purple box; 4 the green box; and 1 the orange box. On the other hand, in another open-ended question, the students were also asked if any puzzle was easy (Figure 8). Twenty students responded that no box was easy; 8 considered the puzzles neither easy nor difficult (so-so); 8 considered the orange box the easiest one; 7 the purple box; 6 the green box; 2 the blue box.

Based on the opinion of one of the students, the fact that none of the tasks in the boxes were easy to perform made the escape room “really cool”. Some students also said that playing the game without paying attention to the hints provided in the boxes made the game difficult, but if one paid attention to the details, the activity became partially easy to perform. The students also described the digital escape room as a “very dynamic activity”.

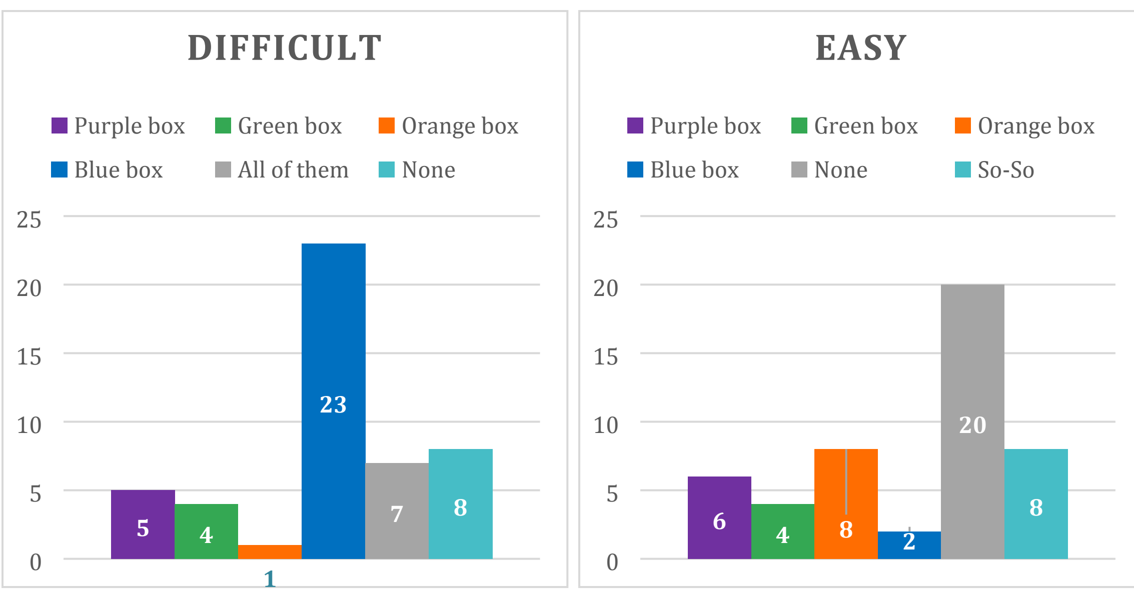


Figure 8. Difficulty of the tasks in the boxes, responded in an open ended-question and categorized by authors (n=48).

The purple box was the second most mentioned box as the hardest one. This puzzle was considered by the authors as the easiest one, as mentioned above. One student who considered the purple box was the most difficult commented that once he managed to solve it, he understood how the game worked. It was also noted by the authors during the gameplay, the WhatsApp groups that took a long time to solve this box were stuck because it took them a while to understand they needed to relate the colored squares with the amount of glassware. Therefore, they had no difficulty with the concept of chemistry, but with the logical reasoning required. However, it was also observed, when they managed to open the purple box, these students had less difficulty in the others, as they understood how the game worked.

Based on the students' informal observations, the digital escape room for learning chemistry concepts and models was very useful in the sense that the activity was structured in a much more stimulating way which was entirely different from the activities they usually have in their classrooms. Student 1 considered the activity more dynamic, compared to a traditional theoretical class. Student 2 and 3 commented that they really liked it and it was an activity which they get more involved with chemistry and could learn from it in a different and interactive way, because they are tired of just picking up paper, writing, memorizing and do some exercise. Also, it is noted this activity was different because they had to solve everything and reach their own conclusions on their own. This comment highlights the fact the escape room is a tool that can develop autonomous learning of participants[5].

Student 1 commented the game is a chance to learn more about the content and even remember things studied that got lost in memory; and after they had played the game, they could see an ionic chemical bonding in "everything", unlike before, which only had formulas memorized. Student 3 noted this type of activity can engage people who like to study and those who don't, because when it's a game you want to learn that thing to get to the end. It can be observed the students considered the escape room useful in the sense that it helped them review the contents covered, like chemical bonding, indicated by student 1. Furthermore, the students pointed out that the activity was tailored in a way that it was able to actively engage both the students who like chemistry and those who do not.

When asked whether they were able to learn something from the activity, the students stated that the activity contributed toward improving their understanding of chemical concepts, laboratory glassware utility, logical reasoning, and the history of thalidomide and its relationship with phocomelia. They also said the activity enabled them to learn to work under pressure and pay attention. However, learning to work in groups was the aspect most perceived by the students. The importance of fellowship, union, helped them to complete the game successfully.

These observations are in line with the findings reported in previous studies which stated that the participation in this type of activity can create positive results in students' cognitive, behavioral and teamwork abilities[5]. The escape room activity is also considered a good form of communication and interaction, which ultimately innovates and brings new ways of acquiring knowledge and developing remote learning[5].

At the end of the game, most of the participating students congratulated the game's production in the WhatsApp group, they presented positive feedback both to the game's scenarios and to its hosting location (Genially). WhatsApp groups for interaction between participants and Genially as an escape room hosting tool were chosen to overcome the indication in the literature that students preferred the physical escape room to the digital escape room[18], mainly because of teamwork and the immersive environment.

CONCLUSIONS

This paper reported the development of a digital educational escape room for high school students using Genially and WhatsApp for aid understanding of basic concepts in chemistry and mostly enhance students' class's participating during the COVID-19 pandemic. The application of Genially and WhatsApp for the design of the escape room was found to be suitable for the purpose of the work. The students who took part in the escape room reported that group work played an important role in helping them complete the activity, and the use of WhatsApp chat groups facilitated students' interaction and stimulated collaboration between the participants. The students also provided positive feedback about the activity and reported that the game allowed them to have fun and learn at the same time. The results obtained from this study also helped identify students' difficulty when it comes to solving puzzles related to their ability to logical reasoning. The study was found to have some limitations. For the conduct of further investigations intended to improve the reliability of the digital escape room developed in this study, one will need to perform a learning questionnaire before and after playing the game, to investigate student learning. Future research on the improvement of students' learning experience should be devoted toward creating different opportunities for students to interact more through WhatsApp; evidently, this will help stimulate dialogue between the students, as well as between teachers and students. Considering that most Brazilian students are deprived of computers, the use of the Genially/WhatsApp-based learning instrument was found to be readily suitable for improving the students' learning experience.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.XXXXXXX. [ACS will fill this in.]

Link to access activity and boxes codes. (DOCX)

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and are submitting the manuscript for consideration for publication as an article including the non-text material such as figures or charts (the “Article”) to the journal *Journal of Chemical Education* published by the American Chemical Society (the “Publisher”) including in some instances in conjunction with another organization as noted below. The parties are consequently entering into this publishing agreement (the “Agreement”). The Authors confirm the information in the “manuscript details” box below.

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