

Chapter 19

Chemistry Edutainment: A Storytelling Activity for Middle-School Children

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ABSTRACT

Creating a fun, interactive, and useful science activity for teaching purposes can be a real challenge, especially if it is addressed to middle-school children. More and more science communicators are employing novel communication techniques to better reach out to their audience. In science communication, storytelling is valuable to sparking interest in science. Given that there are many episodes in the history of science that can serve as inspiration, the authors of this chapter share how they used storytelling, based on a real-life event, to create a science communication activity for middle-school children. Focused on chemistry and ethics, these topics were introduced through hands-on laboratory activities with ethical questions embedded in the story line. This task challenges the students to come up with answers by themselves, through a problem-based learning model. By adding game logic elements to this activity, the authors created a unique form of communicating science, both educational and entertaining, which children appreciated.

INTRODUCTION

In this chapter, the authors will discuss in detail how they transformed an event from the history of science in the 19th-century, known as the “Crime on Flores Street”, into a storytelling-based activity focused on chemistry and ethics, thus calling it “Ethics against Chemistry”. This chapter emphasizes the potential

DOI: 10.4018/978-1-7998-6605-3.ch019

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use of storytelling in science education, presenting a framework of a new science communication activity, which was well-received by the students.

“Ethics against Chemistry” was designed for middle-school students, to be used in a non-formal classroom environment. Moving through the sections of this chapter, we will explore all stages of storytelling development, including the adaptation of the real story into a student-friendly activity, as well as the association of storytelling with gamification. Following the introduction of the concepts of storytelling and edutainment, section two of this chapter presents the activity outline, addressing the general aspects of its framework. The primary focus will be on structuring the activity whilst addressing our proposed goals for student interaction. In the following section we present in detail our activity framework. Firstly, a review of “Crime on Flores Street” is presented, to explain key aspects retained in the activity design. Then, the focus will turn to the storytelling adaptation of this case, detailing key aspects such as its history, characters, and student engagement. The section ends with a clear-cut explanation of how the gamification elements were added to the activity, highlighting the connections made with the edutainment and storytelling framework. The addition of game logic elements has turned this activity into a form of entertainment without neglecting the educational side, thus creating a unique form of chemistry and ethics “edutainment”. The next section of this chapter contains the assessment of the activity. We will focus on the feedback given on the activity, specifically in its storytelling and edutainment components. This part of our research aims to analyze the suitability of this approach from the students’ perspective. In the final section we discuss the challenges and possible research opportunities created by this work.

Previous results of this activity were presented in the following conferences: XVII ENEC / III International Seminar of Science Education in Porto (Portugal) and *Encontro de Ensino e Divulgação da Química* in Coimbra (Portugal), both in 2019.

BACKGROUND

Edutainment

Edutainment is a challenging learning methodology that tackles many problems of traditional forms of education. The student is the focal point of the learning activity, making edutainment a dynamic part of the educational process. Students can express their preferences based on their experience and learning interactions. Teachers, on the other hand, can use this information to improve their outputs (Johnson, 2010, p. 55; Zhigeng, 2019). Learning new skills while gathering experience and feeling emotions while being entertained is pivotal for this educational method (Donovan, 2010, p. 138). Edutainment positions itself as an entertaining mechanism that can provide knowledge to many people, while being aesthetically appealing (Buckingham, 2005, p. 41). But the key factor of this methodology is the informal approach of the lessons. As such, extensive or highly dense subjects are treated in a way that is more appealing to the audience (De Vary, 2008, p. 35; Sorathia, 2010, p. 265). Broadly speaking, edutainment comes as an amalgamation of the concepts of ‘education’ and ‘entertainment’. “Learning from entertainment” requires an establishment of gamification practices to renew traditional forms of education. In other words, it tackles the students’ lack of focus and interest (often cited as one of the major issues in traditional learning methodology) by providing them with opportunities to create a positive learning experience (Zin, 2010).

Current research on edutainment methodologies usually presents two routes of educational strategies: the use of entertaining elements or the integration of educational content into an entertainment sphere.

Many authors take a step further and associate edutainment with game-based learning, as it better embodies this concept (Johnson, 2010, p. 55). The pedagogical elements in edutainment are frequently associated with the learning pace of students (Okan, 2003, p. 255). They can be considered as (Networking, 2009):

- **Relevance Learning:** when the students are engaged by the significance of the topics.
- **Incremental Learning:** when students learn at their own pace.
- **Distributed Learning:** learn at different periods.

Edutainment is rising in the educational community, as it helps to combine effective hands-on experiences with specific skills they aim to convey (Zhigeng, 2019). In another stance, it can be a useful tool to combine real-life experiences with several educational formats.

Several articles refer to various forms of entertainment, primarily mentioning transmedia outlets such as television, digital/social media, and video games (Jarvin, 2015, p. 33; Sorathia, 2010, p. 265; Zhigeng, 2019). Moreover, edutainment can also be considered as a hybrid genre that relies heavily on narrative and gamified formats to address educational topics in an informal way (Okan, 2003, p. 255). Gaming approaches can be powerful when embedded within educational strategies. Applying gamification-based activities can promote student learning: individually or in a group, students can explore, perform trial-and-error actions and repetitions in a fun way, without realizing that they are learning at the same time (De Vary, 2008, p. 35).

Types of Edutainment

On addressing the issue of creating and implementing a storytelling-based edutainment activity, it must be clear which categories one must fit to their design. One can design an activity to be interactive, passive, or a hybrid (with mixed tasks requiring involvement). According to White (2003), at an organizational level, one can define the types of edutainment based on their:

- **Location:** An interactive and participatory activity where the user becomes an active participant and a non-interactive activity where the user (or spectator) is just seated and exploring.
- **Purpose and Content:** Informal education to improve the participants learning skills by providing new experiences.
- **Target Group:** Motivation and age-oriented (participants who share some interests).
- **Type of Media:** Either audiovisual (TV, film), computer/digital or internet based.

Storytelling as an Educational Tool

Telling stories is an intrinsic multi-sensorial human connection tool. The intrinsic value of orally expressing a story can be one of the most powerful driving forces of human imagination. As such, it is legitimate to think of storytelling as an educational tool. And even more so if the story portrays a fantastic tale of human endeavor.

A compelling story has powerful effects since it can unite an idea with an emotion. Stories seem to be a product of evolution, as they have allowed us to simulate reality and to predict the outcome of relationships. As such, narratives are easier to comprehend and are associated with a high recall rate (Dahlstrom, 2014, p. 13614). Stories have been recognized as a communication vehicle in many edu-

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cational applications (Schank, 2002, p. 287-314). They can engage the people's imagination regarding a specific topic, empathetically. This is especially noticeable with young children, as their perception of the real world comes from the guided experience of other people. Despite not being a "hands-on" activity, storytelling can span a more transcendent range of emotions in young students.

Physical experiences can certainly make an instant impact on children, but they are volatile (Schwchow, 2016, p. 980). They are more prone to understand and recall specific pieces of information if they are transmitted within the plot of a story, rather than by a conceptual arrangement (Schank, 2002, p. 287-314). It is important, particularly for young students, that abstract concepts be presented in a way that they can easily comprehend (Avraamidou, 2009, p. 1683).

The pedagogical reputation of storytelling is demonstrated in many excellent studies (Haven, 2000; Truby, 2007). In a more practical approach, one can understand storytelling as an educational tool whose effect is threefold: it generates awareness of a new topic; introduces the student into a new reality; and encourages reflection and integration of (new) concepts (Caine, 2005). But most importantly, it can be engaging and entertaining. The ability to involve students at an emotional level can be the driving force towards a more "active engagement" on their behalf. This paves the way for new forms of teaching school subjects, ranging from mathematics, science, history, and even linguistics (Rose, 1997).

If one's objective is to introduce students to science and how science is a part of their world, one must introduce it in a fashionable way. First impressions are everything when talking to middle-school students, as one can imagine. Even more so when discussing topics hard to introduce, such as chemistry or physics. One way to face the issue is to flip the perspective of students. Letting them see with their own eyes how a scientist solved a problem can surely help. Or better yet, let them try to solve the problem, helping them perceive scientific problem-solving. And a good starting point would be to approach science as a story. A "historical narrative" can easily become an icebreaker to teach the way nature is understood by scientists (Schiffer, 2014, p. 409). However, the plot of the story cannot be just a bland copy of historical reports. For students to understand the fundamentals of science in action, several concepts must be highlighted. As previously reported (Heering, 2010, p. 323), there are four major plot points that a scientific-based storytelling activity must include:

1. Scientific knowledge, while durable, has a tentative character.
2. People from all cultures contribute to science.
3. Scientists are creative.
4. Science is part of social and cultural traditions.

Chemistry subjects can be easily implanted in this environment. A good form of teaching science subjects through narratives is to demonstrate that science is no more than a human endeavor (and a search for answers). It consists of the accumulated stories of regular men and women trying to find answers to their questions. The hardest part, in this conception, is to find a story that can fit these criteria. When addressing a school science question, the story cannot be just about finding an answer to a certain quiz. It must evolve into a problem to be solved (problem-based learning), surrounded by a certain shroud of mystery and engaging elements. From this perspective, studies point out the positive outcomes of such an approach, especially when it comes to enhancing student learning outcomes and motivation with scientific topics (Corni, 2010, p. 1; Morais, 2015, p. 58).

Storytelling can provide new ways of addressing science communications to a broader audience, namely to middle-school children. By capturing their attention and promoting overall enjoyment, the

latter can be engaged with the scientific activity, and control their learning process, building up their motivation, interest, and curiosity regarding a specific topic. In this sense, gamification can also be a useful way to improve the students' engagement, by adding game elements to a non-gaming context, such as challenges/tasks or win/lose logic. One can make science learning more dynamic, interactive, and ultimately fun.

Storytelling Adaptation

What must be the primary directive when casting a storytelling plot to address scientific topics? The focus should be on creating (or adapting) a story that aims not to provide an answer to a question, but rather an answer to a problem. And the story should not be too technical or methodical, as it can easily distract the students. The content must be wrapped and delivered in some form of a ludic template, to engage the students' imagination and abstract perception. Therefore, the story (either real or fictional) must provide:

1. A clear problem that needs to be answered.
2. The existence of several theories for its explanation.
3. The successful (and especially the unsuccessful) experiments towards the answer.
4. A proper closure, with the dissemination of the theory.

A story can be defined as a sequence of related events, although a few additional issues must be considered:

1. They unfold at the right pace, matching the audience's ability to follow the story.
2. They hook the attention of the audience with interesting plots, settings, and characters.
3. They leave a lasting impression, spiking the audience's curiosity, which makes them want to know more.

The pace of the story is quite subjective, as it could seem to move too fast or too slow to distinct individuals, depending on their different tastes and attention spans (Ma, 2012, p. 12). There are various ways to trigger one's attention to our story. Mystery and building up suspense are key factors to properly engage with the audience. When something out of the ordinary occurs, with no apparent explanation, it can arouse the natural sense of curiosity in human beings. Not knowing what happened makes the audience want to know more. Several episodes with this prerogative can also be good candidates for storytelling. But one type is becoming prevalent in TV shows, series, or books: an unexpected murder and the story of the team that tries to solve it.

Our minds were set to address the emergence of analytical chemistry in Portugal, whose development accompanied some dramatic criminal affairs. From the early works in antiquity to the thriving of modern chemistry in the late 19th-century, several stories can easily spark the interest of an audience, even children.

ETHICS AGAINST CHEMISTRY: AN EDUTAINMENT ACTIVITY

Activity Overview

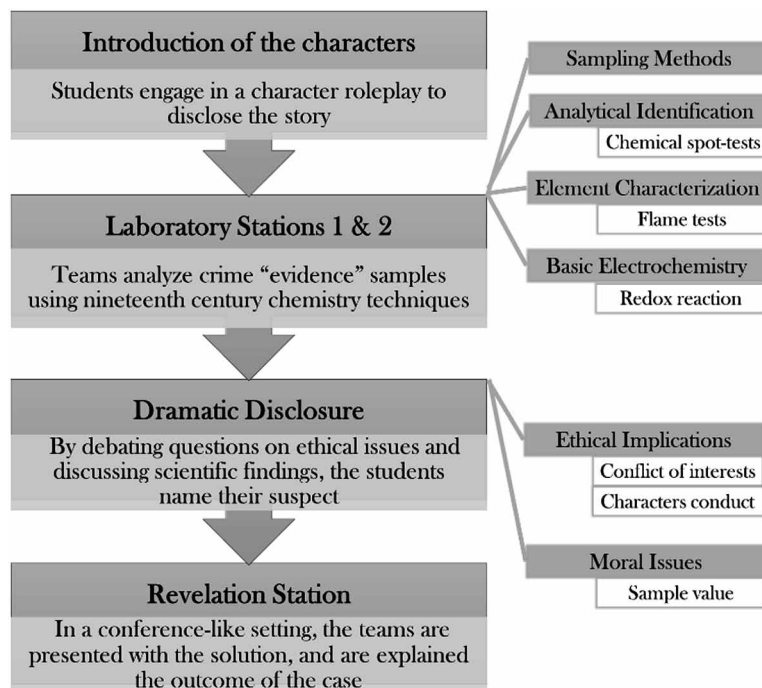
The purpose of combining these different forms of communication and learning techniques was to create a scientific activity that was easily understandable, but most importantly, interactive. Thereby, it could serve as a tool that could both provide entertainment and knowledge in various areas. “Ethics against Chemistry” is an educational science dissemination activity of chemistry and ethics, integrated into the program of the 2019 Junior University, a Summer curriculum that introduces children to the University environment; in this case, the University of Porto (Portugal), in the Faculty of Sciences. From all over the country, about 280 Portuguese speaking students were divided into classes by the organization of the Junior University. Each day, a different class of about 14 students participated in this activity. The middle-school students, under fourteen years old, were invited to perform a series of hands-on activities within an educational scientific game. As stated before, this is a novel approach focused on storytelling, based on real figures in the Portuguese history of science and technology in the 19th-century. These real-life characters partake in a forensic murder-case, one that is seldom explored.

It all comes together in a board game (Figure 8), composed of “stations”, challenging the students to fulfill a game report on their smartphones to complete the game, guided by two teachers, that also evaluate the reports and chose the winning team. The hands-on activities were planned to mimic the chemistry laboratory techniques available in the 19th-century. The participants play the role of 19th-century scientists/investigators who will have to follow the scientific method and perform actions like correct analysis of crime-scene samples, handling/treatment of samples and data, and execute the most effective scientific procedure. They will do so based on their methodical decisions, as they obtain clues to unravel the enigma.

Students will have to team up to resolve this murder-case, facing scientific and ethical challenges, inspired by the real-life story, in the same way as the characters were. As a request to finish the game, the students articulate their findings in a “conference-like” presentation and are encouraged to argue the scientific and ethical implications of the procedures they used earlier.

In Figure 1 we can see that Stations 2 and 3 represent the laboratory stations, in which the students analyze the samples of the crime scene, in a pre-prepared laboratory. The laboratory procedures are written down so the students can follow the protocol of experiments. Their aim is to determine the composition of the samples, through chemistry techniques. It is up to the students to handle the material correctly and to draw their conclusions. Teams must take turns to use the laboratory stations. The samples provided for analysis are Oxygen Peroxide, Hair Sample, Copper Sulphate, Ascorbic Acid, an Alkaloid, and Borax solution.

Figure 1. Schematic summary of the structure and goals of the activity “Ethics against Chemistry”



The participants were introduced to the samples not knowing what they represent, although the teacher states that at least one was used as the murder weapon. The teacher helps them through the laboratory experiments, to identify all the samples presented. Then, the students write down their findings and interlink the results with the story elements provided by storytelling media. The most attentive students will be able to link these elements with the practical information obtained from the scientific experiments.

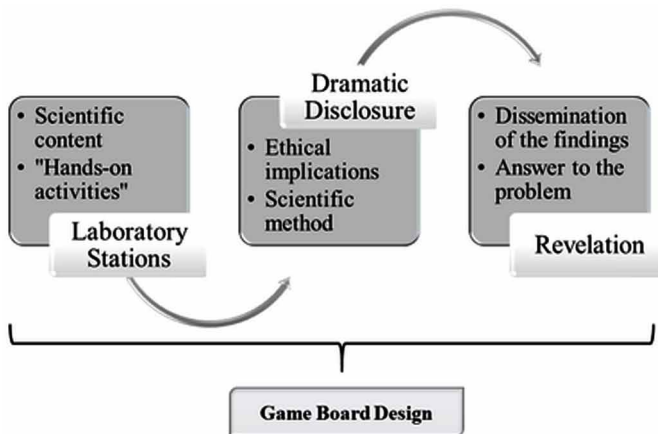
Building an Activity Framework

Design Layout

In this section, the design layout of the activity is designed as a general blueprint of the way the activity was drawn up. The initial idea was to determine what elements must be intrinsically reproduced in the gamification setup. The first step is to identify a vehicle and/or anchor for the student engagement in the story. For practical reasons, and favouring a “hands-on” approach, the vehicle chosen was a gameboard.

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Figure 2. Scheme of the selections of topics and activities that resulted in the gameboard of “Ethics against Chemistry”.



The following stage is to set up what needs to be disclosed in the gameboard. It was clear, right from the start, that the scientific element needed to be omnipresent in the game. However, by itself, it is not enough to engage with the students. There must be a methodical path that interlinks the science activity/explanation with a dramatic and emotive disclosure of the storytelling element. And so, as revealed in Figure 2, the laboratory stations are the catalyst for students' interaction and participation in the game. It is from them that they will be able to draw vital information needed for game development. Therefore, we have designed one practical stage (Laboratory Stations) and two storytelling stages (Dramatic disclosure and Revelation).

The storytelling stations are essential to involving students in the development of the story. Through them, with added knowledge from the laboratory stations and the revelations of the characters, they will only move forward if they are able to identify specific key aspects. In the Dramatic disclosure, the students will need to face the ethical implications of their decision regarding their answer to the question in the game, along with the evidence provided by the scientific stations. Even more, they can only obtain the final answer if they can successfully argue why they chose that answer, based on their findings. This is crucial to make students feel a part of the story and for being able to provide a continuous focus of attention after the scientific activity (so as not to lose engagement in the storytelling sections).

Introduction to the Real-Life Story

Choosing an episode from the history of science was challenging, as popular stories or well-known stories within a culture might not be a good option. The audience might lose interest in the plot, after all, they may already know how it ends. Since our activity was designed for Portuguese middle-school children, we intentionally limited our options to events that took place in Portugal as our audience was composed of Portuguese speakers. This way, we could establish a deeper connection with them. Therefore, we chose an unknown story for the age group, although quite popular at the time, the “Crime on Flores Street”, a mystery tale that leaves the audience questioning why a rich doctor wanted to kill his family for more

money. In this crime-solving drama, populated by characters with unanswered questions and the feeling of injustice upon a child's death, all these factors contribute to engaging the audience with the story.

To fully understand this activity, we will explain below how this story was transformed into an educational activity, but first, we must tell the real story, at least what is known.

Our story takes place in the 19th-century Oporto, Portugal, where a brilliant doctor called Vicente Urbino de Freitas was convicted of murdering his nephew, Mário Sampaio. Urbino de Freitas was married to Maria das Dores Basto Sampaio, daughter of Maria Carolina and António Sampaio, a rich merchant. Maria das Dores was the youngest of three brothers, Guilherme Sampaio (who died but fathered two kids: Mário and Maria Augusta), and José Sampaio Júnior. Júnior fell in love with Miss Karter Lothie after his wife's death, though he died in mysterious circumstances (involving Urbino de Freitas).

Four months after his death, tragedy strikes the Sampaio family again. The grandparents António Sampaio and Maria Carolina receive a strange package with Easter sweets that were distributed to their grandchildren. The girls complained about their bitter taste, while Mário ate his entire portion.

Suddenly, the children started to feel sick. Maria Carolina gives them fruit salts and they sleep through the night. The next day, Maria Carolina calls for help, explaining to Urbino de Freitas what happened, and he prescribes warm water and coffee (R. J. Dinis-Oliveira, 2018, p. 69). Later, Urbino de Freitas prepares enemas that are given to the children by their maid, Maria Luísa. The girls expelled the enema as soon as their uncle leaves the house. Mário, on the other hand, followed his uncle's instructions and kept the enema for as long as he could, and was rapidly getting worse. About to leave the house, Urbino de Freitas explained to Maria Carolina that the children were poisoned, and they should call Adelino Leão da Costa, another doctor, for help. Freitas told him that the children were poisoned from the Easter sweets without revealing his enemas' prescription. Hours later, Mário died.

Suspicious started to build up around Urbino de Freitas, due to the testimony of Miss Karter. She promptly collaborated with the police, revealing that the murderer must be someone in the family, as José Sampaio Júnior had died a few months before, with the same symptoms as Mário Sampaio. Therefore, forensic experts from Porto were called to analyze samples from Mário Sampaio's body (already buried) to determine the poison used. This story caught the attention of the national press (Marques, 2019, p. 48), and between toxicological tests and trials, more than 3 years passed.

Freitas was convicted of murdering his nephew in order to obtain the family fortune, though he fought all his life to prove his innocence. In court, toxicological reports from analysis of the victim's body, provided by a team of chemists led by António Ferreira da Silva, were critical to solve the case. Due to his contributions in this case, Ferreira da Silva is considered by some authors as one of the most prominent Portuguese forensic chemists.

This was a controversial and dramatic case for the Portuguese justice system, not short of scandals: criticism fell on the toxicological analysis, and on the previous love affair of the public prosecutor with Maria das Dores. As of today, this case still has a lot of details being studied (R.J. Dinis-Oliveira, 2019, p. 17-19).

Storytelling Adaptation

As previously stated, a storytelling adaptation must follow four basic steps to ensure its viability. In this section, we describe how we adapted our story to this framework. The fundamental steps in the conception of "Ethics against Chemistry" are:

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1. **Address a Clear Problem that Needs to be Answered:** Our story highlights several problems that can be addressed. It should be noted that we must not dismiss any aspects of the story, as they can be used in later sections. The problem is simple: who committed the murder? It is a simple question that needs closure, and it is easily understood by the students.
2. **The Existence of Several Theories for Problem Explanation:** Using the elements provided by the real story, one can build upon several theories for how the crime occurred. The plot should emphasize the relations of the main characters and how they can lead to possible lines of thought in the story. In this case, right from the start, the poisoning of the victims was thought possible. Despite this being the primary theory, other ramifications emanate from this iteration: who poisoned whom? For what purpose? All these questions lead to other theories that can explain the main sequence of events and help develop character storylines.
3. **The Successful (and Especially the Unsuccessful) Experiments Towards the Answer:** This is, perhaps, the most important issue in this framework. The plot must provide sufficient elements so that the problem could be solved with a scientific query. In this case, since it all points towards a poisoning felony, it is easy for students to comprehend that the poison (the “murder weapon”) should be identified, therefore requiring scientific methods to solve this problem. Presenting scientific experiments as a tool for solving crimes can induce the idea of “science in the service of everyone”, with actual applications that influence our daily life. We also stress the importance that these experiments can be flawed, in the sense that it is not always clear, right from the start, what to test and how to test it. This is the opportunity to present science as a “human endeavor” made of rules and terms of engagement. Concepts like “experimental planning”, “sampling”, and “data collection” can be introduced to familiarize students with the specific line of thought in executing a scientific experiment. We chose to introduce several tests congruent to the story, but only one of them expressed the right answer. That way, it is easy to portray science work as something made of trial and error, and not just accessible at a click of a button.
4. **Proper Closure, with the Dissemination of the Theory:** After the students had the experience of how scientific knowledge is built, they also must know the proper way to disclose their findings. With respect to the real case, since it involved a trial, it is easy to portray it as an ideal scenario to reveal the conclusion of the experiments. However, a case can be made for a revelation step in a more appropriate scientific environment. For example, the staging of an academic conference or a science class can be an ideal place where students themselves can present the results they have recorded. That way, the intrinsic procedures of public speaking, presentation, and argumentation are being subsequently learned by them. It is a simple and effective way of allocating some of the credit for the development of the story to the students who partook in it.

The narrative construction and gamification adaptation of this activity were constructed by extracting the elements cited above from these four basic steps. All the features of the story were inspired by the outtakes produced from the previous analysis.

Characters' Selection

We have described, with some detail, the real-life story of the “Crime on Flores Street” in a previous section. The first step was to choose which details of the real story would be used in our activity (such as characters and locations). It is important to choose a starting event within this story that could trigger

the interest and curiosity of the audience. And, as we stated previously, adding a mysterious death can serve as a decoy to catch your audience's attention. Therefore, our starting point was the murderer of Mário Sampaio. We could have chosen the death of José Sampaio Júnior (although it is mentioned by the teachers) but did not for two reasons: 1. Vicente Urbino de Freitas was not convicted for his death in real life (R. J. Dinis-Oliveira, 2018, p. 69); and 2. Mário's death was the starting point of the plot.

We decided to reduce the number of characters to those essential for storytelling adaptation. Nonetheless, the characters that were cut off did not interfere with the overall premise. Then again, we added some details and relationships between characters to avoid directing all suspicions towards Vicente Urbino de Freitas.

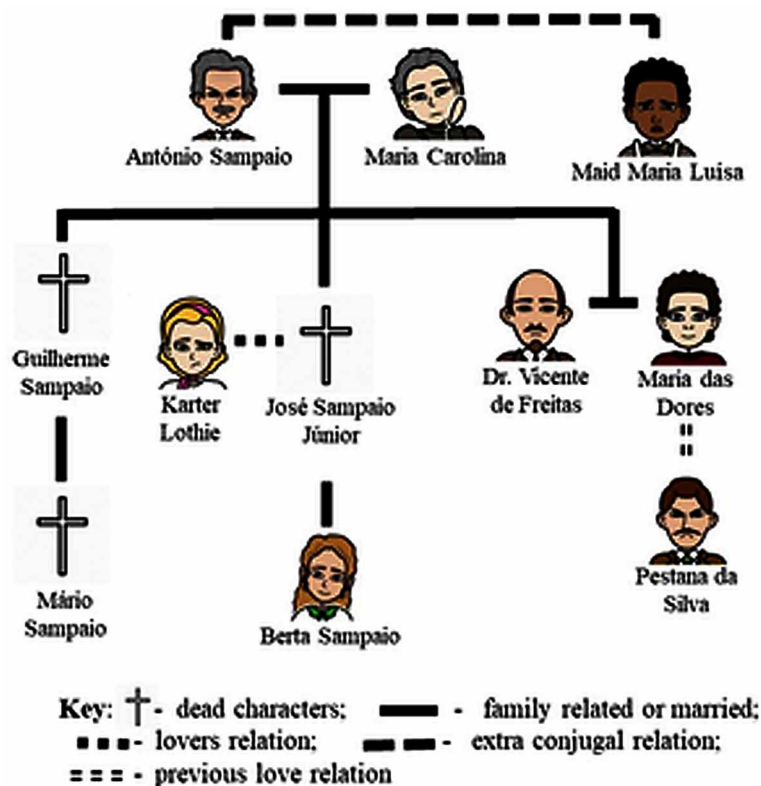
Some story elements and the relationships between the characters were intentionally changed, although they in no way taint the scientific findings from the hands-on experiences, nor change the culprit. And, by doing so, we were able to test if the students are more drawn to cast conclusions mounted on scientific arguments.

All the characters included in the story, together with the backgrounds, were created in Storyboard-That,(2020) a platform for digital storytelling that enables the creation of graphic novels and comics with a lot of options of personalization.

The main characters of the Sampaio family, and those closest to them, are represented in Figure 3. Since our story begins with Mário Sampaio's death, he is represented with a cross. At this point, his father, Guilherme Sampaio, and his uncle, José Sampaio Júnior were also dead, so they are also represented by crosses. The wives of both men do not exist in the story. However, in José Sampaio Júnior's case, the teachers mentioned that he had a wife who had died before the event and that he was in a relationship, at the time of his death, with Karter Lothie, who was not the mother of Berta Sampaio. Berta Sampaio was the only granddaughter who was kept in the story, since she was old enough to "be questioned" by the police. We only needed one of the girls to contrast her actions with Mário's: in the real story, he ate the whole portion, the girls did not; he followed Dr. Vicente de Freitas's instructions regarding the enemas, while the girls did not.

Only one help is represented here, as the wealthy family is described to also have a cook (Dinis-Oliveira, 2019, p. 10). Maria Luísa was the maid, and we wanted to make her a 'scapegoat', making things a little more complicated, mysterious, and interesting. And for some reason, in this type of activity, a lot of people suspect the help first. Thus, we have faked a relationship between her and António Sampaio, which resulted in her getting pregnant. In fact, the script of this first part is written so that the characters "accused" each other. We will detail that in the next section.

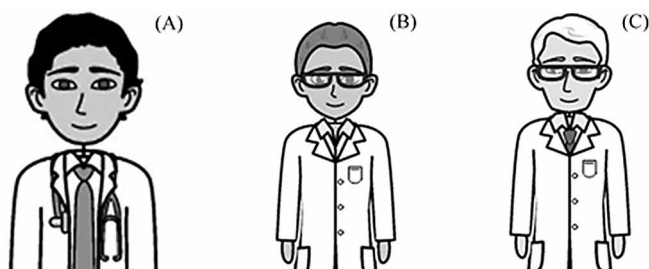
Figure 3. Recreation of the Sampaio family tree for “Ethics against Chemistry” activity.



Lastly, we slightly changed the name of Vicente Urbino de Freitas to Vicente Freitas, to avoid the chance of the students finding out about the real story, by a simple Internet search.

These are all the characters that appear at the beginning of the story. Each one of them tells what happened, or what they thought happened to cause Mário’s death. As the characters share their thoughts and feelings, this brings the audience closer since it seems as if they were speaking directly to them.

Figure 4. Characters outside the Sampaio’s family: (A) Adelino Leão da Costa, (B) António da Silva, (C) Augusto António Rocha.



The last character on the tree is Pestana da Silva, the public prosecutor, who later accused Vicente Urbino de Freitas of murdering his nephew. However, his actions were questioned because of a previous relationship with Maria das Dores, and he was accused of acting out of jealousy (R.J. Dinis-Oliveira, 2018, p. 10). He only appears towards the end of our story.

Figure 5. Representation of António Ferreira da Silva.



Besides Vicente Urbino de Freitas, other doctors attended the house of the Sampaio family to treat the ill children. Again, here we reduced the number of characters for simplification purposes and incorporated the medical doctor Adelino Leão da Costa (Figure 4A), who performed the autopsy of Mário Sampaio in real life (R. J. Dinis-Oliveira, 2018, p. 69). He could also give the audience a second opinion upon the treatment given to the children.

As we stated before, toxicological tests were performed in real life and there were two Portuguese laboratories involved, one in Porto and the other in Coimbra. Therefore, we added characters that could speak on behalf of these laboratories: António da Silva from Porto (Figure 4B) and Augusto António Rocha from Coimbra (Figure 4C). In real life, Augusto António Rocha was a medical doctor and professor at Universidade de Coimbra who was asked by the defence of Vicente Urbino Freitas to help in the case. This was a controversial choice, as Augusto António Rocha had studied medicine with Vicente Urbino de Freitas (Leonardo, 2009).

Our final character had relevant participation in this case in real life: António Ferreira da Silva (Figure 5). At the time of the murderer, António Ferreira da Silva was a chemistry teacher at Academia Politécnica do Porto (1877-1910) (Ferraz-Caetano, 2019, p. 213). His discovery of new reactions for alkaloid analysis was published in the Academy of Sciences of Paris. And since Vicente Urbino de Freitas was accused of using alkaloids to poison family members, Ferreira da Silva was asked to help (Martins, 2018, p. 244).

Script Composition

After selecting our characters, the next step was to give voice to them and it was particularly important that the characters spoke directly to the audience, recreating almost an open dialogue and creating a deeper connection with the audience. Otherwise, the characters would only confront each other, putting

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distance between the story and the audience, leaving the audience as a third party, and feeling left out. This could increase the levels of the distraction of the audience.

To solve this issue, and to involve our audience in the story, we gave students a role. This way, they felt like they were participating in the story. And since there was a murder to be solved, the students assumed the role of the police investigators who were trying to solve the case. By doing so, the audience role-play could interact with the characters, hear and see what happened.

The first animation from *StoryboardThat* sets the tone of the activity and the teachers set some of the rules, guiding the students through the game. As the audience assume the role of police investigators, they receive the instructions from their chief, who assigns them the mission to crack this case and to write everything down, as there could be some useful information. The chief then orders the police investigators to head down to the scene of the crime: the Sampaio family house and interview whoever is inside.

Although our characters and environment match the 19th-century, the language used and the dialogues of the characters were kept in the 21st-century, to avoid linguistic entropy and to make it legible for our audience. The language used in the 19th-century is context-bound and it has its particularities, which could be hard for a fourteen-year-old to understand. The characters' message could be lost in translation, preventing the story from coming through.

Since there are a lot of characters and our audience was made up of middle-school children, the script was written to interchain characters of the Sampaio household. In other words, when the police investigators interview a character in a room, that same character reveals the name of someone else in the household, who is usually interviewed subsequently. The characters always direct their speech to the police investigators, except for António Ferreira da Silva, who appears last and speaks to a chemistry class, while Pestana da Silva speaks to the judge.

Nonetheless, they all tell a small part of the story, which obliges the audience to pay attention to the narrative and reconstruct the whole story themselves. This is not a fluid narrative, where there is a succession of events that occur and culminate in the climax of the story. The characters are almost secondary and are driven by the power of the narrative itself. The purpose of our narrative, in doing the interviews, was to keep it simple in order to help the information sink in, but also to turn on the focus to the characters, as they accused each other of being the murderer. All characters created were static and since they needed to talk, we had to come up with a way to “give voice” to the characters. Therefore, we imported the idea of speech balloons from comic books. This way our characters could “talk”, and we could add as many speech balloons as we wanted, to accommodate all the lines of their speech. Figure 6 and Figure 7 exemplify different characters within the household of the Sampaio family, demonstrating different facial expressions while being interviewed by the police investigators, as they tell their side of the story.

The static images were also limiting in one other aspect: the audience could not ask questions to the characters; their questions were also previously established. Figure 6B shows two speech balloons, one from Maria Carolina the other, in the bottom left corner, belongs to the police investigator.

Figure 6. Examples of the characters and scenery from the Sampaio household, with António Sampaio (A) and Maria Carolina (B) being interview by the police investigators



The audience cannot control the story, they do not have that freedom. Much to the contrary, this type of storytelling can be defined as *passive storytelling* (Ma, 2012, p. 18). However, for this activity, our story had to be set up with a screenplay, as we wanted to guide our audience on the right path to solving the mysterious murder of Mário Sampaio. By not having the freedom to interact with the characters, all members of the audience have the same information, therefore in theory they are all at the same starting point to solve Mário Sampaio's case. We did realize that this passive storytelling may not be enough to engage with our middle-school student audience and thus in the next section, we will describe how we turned this story into an interactive activity, which can entertain the audience.

Figure 7. Examples of the characters and scenery from the Sampaio household, with Vicente Urbino de Freitas (A) and Miss Karter Lothie (B) being interview by the police investigators



The first character to be interviewed, as per 19th-century cultural rules, is António Sampaio, the man and owner of the house. He describes to the police investigators that both grandchildren felt ill but only Mário died, with the same symptoms as his son, José Sampaio Júnior. Then again, when he was told that everyone in the house was going to be interviewed, he responded that the maid, Maria Luísa, only speaks nonsense, so she is not worth interviewing, with an expression of worry, despair and concern about what she could say about the pregnancy (Figure 6A). António mentions that his daughter, Maria das Dores, is in the dining room, so the police investigators interview her next.

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Maria das Dores quickly pushes the blame towards Miss Karter, confessing to never liking her, since she drank funky teas all the time (detail visible in Figure 7B). When asked about the motive Miss Karter could have to kill Mário Sampaio, Maria das Dores said it was all about money, as she always asked José Sampaio Júnior for money. She also mentions quarrels between Miss Karter and her mother, Maria Carolina, concerning the family's money and José Sampaio Júnior.

Maria Carolina, next in line for the interviews, is very upset about the death of her grandson, and by the other family members that she already lost. She reveals that her son, Guilherme, died in an accident and José Sampaio Júnior died in agony, vomiting, treated by Vicente Urbino de Freitas. Nonetheless, like her daughter, she also accuses Miss Karter of murdering Mário Sampaio and José Sampaio Júnior, for the family fortune. In Figure 6B, a vase with roses is visible. This detail is important to recall since roses are cultivated in the house and very appreciated. In fact, Berta Sampaio (a scenario not illustrated here) is interviewed in the garden of the house, surrounded by roses.

Miss Karter Lothie is both stunned and preoccupied that Mário Sampaio was poisoned, as she is aware that she is going to take the blame for it since there are people in that house who do not care about her, nor like her. Moreover, she questions why the children could eat sweets from an unidentified box that the maid brought into the house. She also states that the children were the only ones to eat sweets from that box and were treated by Vicente Urbino de Freitas when they started to fall ill, despite the fact that the remedy he gave them did not seem to work.

Vicente Urbino de Freitas sits at his desk, with a wrapped box and some candy (Figure 7A). As he is being interviewed, he comes across as arrogant, stating that he is never wrong. He tries to diverge attention, launching suspicions upon the fruit salts given by Maria Carolina, as they could have had something added, a blue powder that the maid Maria Luísa saw in Maria Carolina's room. He states that the latter lost her mind over the scandal with the maid Maria Luísa. When asked about José Sampaio Júnior's death, he redirects the claim towards Miss Karter.

The maid Maria Luísa's turn has come, and she claims that the package of sweets was left at the door, with no identification. She brought it to the house as it could be something important, and then confesses that she is pregnant by Antônio Sampaio, who had visited her room at night. She asked Maria Carolina not to fire her and she was kind explaining that she had already lost children, she did not want to lose anyone else that could carry the family's name. When asked about the blue powder that Maria Carolina keeps in the room, Maria Luísa confirms that she saw it and that the mistress said that the blue powder was used on the roses, and was kept there so that the children could not reach it.

The last character that is interviewed is Berta Sampaio, and she tells the police investigators that she was very sick on Easter, as was her cousin Mário. She confesses that Vicente Urbino de Freitas gave them remedies, the enemas, but that she did not take hers. She also states that both of them ate some sweets, and she tried the coconut cake but did not like the taste of it, so she gave it to Mário, who ate the whole cake.

After interviewing the household of Sampaio's family, the police inspectors turn towards the other medical doctor who was also called at the house to treat the children, Adelino Leão da Costa. He states that when he arrived at the house, there was nothing he could have done to save Mário Sampaio, who probably died from something he ate. He also says that Vicente Urbino de Freitas only attended to the children as a request from their grandmother, who insisted tenaciously. When asked about the enemas that were prescribed by Vicente Urbino de Freitas, Adelino states that he does not agree with that prescription, since they are not effective.

This set of interviews concludes the storytelling part, which is important to set the mood of the story, and to introduce some facts to the audience: how the characters are related to each other (Figure 3), what events led to Mário's death, the stories behind the characters and what actions Berta did differently from Mário (whose actions ultimately led to his death). The story pauses for a bit, to give the audience a chance to investigate the crime and try to figure out, in an interactive way, who committed the murder.

The laboratory character António da Silva (Figure 4B) states that they work with new reactions that can identify toxic compounds, a useful technique to help the case. Augusto António Rocha (Figure 4C), on the other hand, states that he knows very well the Sampaio family since he studied medicine with Vicente Urbino de Freitas. He also disdains the work from the laboratory in Porto and calls António da Silva a liar.

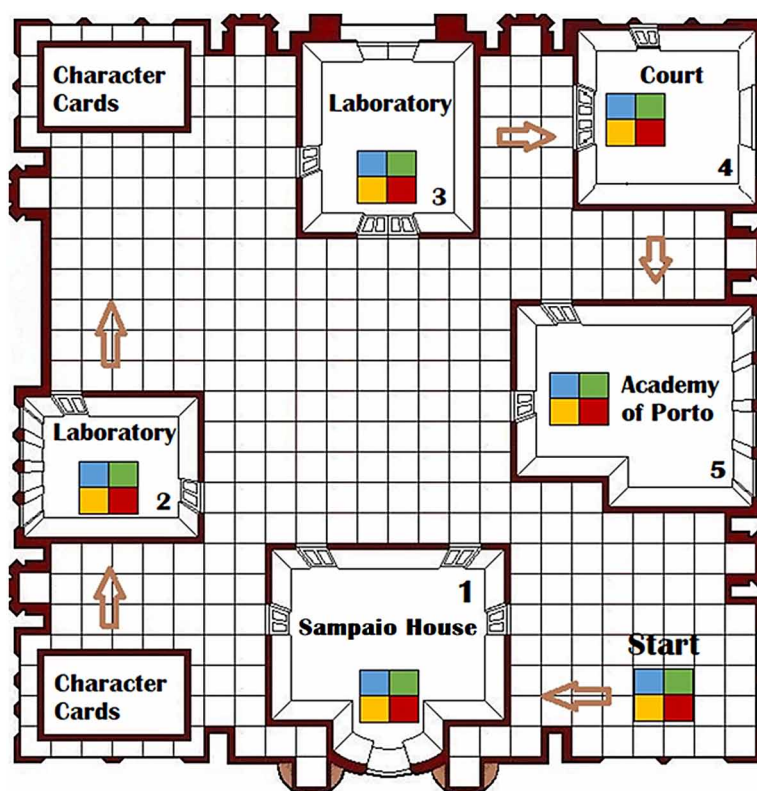
After the laboratory results are back, the storytelling continues its pace, reaching its final stage. The case is brought to justice, and the prosecutor is Pestana da Silva. He states to the court that the laboratory in Porto found the presence of alkaloids within samples of Mário Sampaio's urine, although the laboratory from Coimbra did not find such substance. Even so, he accuses Vicente Urbino de Freitas of murdering his nephew and he also states that he does not like him as a person.

After the trial, the story skips two years and heads to the classroom of António Ferreira da Silva, where he tells the class how he helped solve a case, by creating new techniques to detect the presence of alkaloid substances, which were used to poison Mário Sampaio. And the culprit was Vicente Urbino de Freitas.

Addition of Gaming Elements

The question that remains is: how to transform this story into an interactive activity suited for middle-school students? The answer resides in adding gaming elements, thus turning this activity into a game. As we stated previously, games can be an effective tool to engage children in difficult subjects, and this also includes board games. Therefore, we were inspired by the popular board game Clue®, which included the premise that we were looking for in a game: that the participants play the role of investigators to find out who committed the murder. As we followed this premise, we constructed a board game (Figure 8) according to the same logic design as Clue®. The board game is divided into five major "stations", which are numbered: Sampaio house; Laboratory; Laboratory; Court; and Academy of Porto. The starting point of the game is marked by the position "Start" and above it there is a section composed of four colorful squares: yellow, blue, red, and green. These squares match the colors of the four teams playing the game, named after these colors, and are replicated in each station, to serve as an anchor, to convey a more dynamic sense of space and change of setting as the game evolves.

Figure 8. Structure of the gameboard of “Ethics against Chemistry”



Between the major stations, there are *in medias res* stations that represent a place where the “Character Cards” are laid. Teams will pick up a card whenever there are instructed to do so by the timeline animation controlled by the teacher, which sets the pace of the game. Each card contains an image and a small description of the person. Then, the students will assist at a small interrogation that was already described, conducted by the investigator with a particular character. The cards are made available for consultation throughout the game.

The timeline animation includes the rules and the timing of the next steps of the game. It also incorporates digital storytelling (characters animations) and pauses for group discussions. To change “stations” and follow the game, students must conclude tasks like hands-on laboratory experiments (Laboratory station 2 and station 3) or answer questions, engage in some ethical challenges (stations 1; 4; and 5), available in a pre-determined digital report. This digital report is accessed via the internet at the beginning of the game through a smartphone (one per team).

The gameboard sets the timeline of the game and the storytelling (Figure 8) as the starting point of the game is Station One, the crime-scene house, where the police investigators go first. There, they learn what happened and interview the Sampaio household. Afterward, and as they collect samples from the house, the police investigators go to the laboratories available at the time (Stations 2 and 3) to have the samples analyzed. At least one of the samples was used to murder the victim. With that in mind, each team will proceed to analyze all samples. Next, in Station 4, there is a “Dramatic Disclosure” moment, brought about by the character Pestana da Silva in the trial of this case. The teams are encouraged to

debate orderly, as to make their arguments on who is the culprit. Finally, Station 5 is the “Revelation Station”. The students are presented with António Ferreira da Silva’s story to his class how he helped solve this case. He reveals who committed the murder and what poison was used.

Figure 9. Word cloud containing the answers given to describe “Ethics against Chemistry” (free translation by the authors).

Source: WordArt.com, 2020



As part of the gaming strategy for this activity, we have added compulsory laboratory experiments that students need to participate in. They serve as plot points in which they analyze all the samples presented along the storyline, bearing in mind that at least one of them was used to accomplish this crime. Consequently, they will use the experiments to determine the murder weapon. In this part, the role of the teacher/supervisor is pivotal. Each experiment is presented with a series of protocols and safety warnings that ensure the completion of each task. In order to help students complete all laboratory queries, teachers will provide aid, on a step-by-step basis, during all stages of the experiment, making sure students are aware of the scientific concepts behind each action. We highlight that all experiments were designed to tackle specific chemistry issues that students were familiarized with from their middle-school syllabus. Bellow we present a quick remark on the experimental contents.

Experiment 1: the purpose is to compare current analytical methods with the techniques used in the 19th-century. For that, students will analyze hair samples and compare their magnified samples with model strains of types of hair. They should conclude that it was not possible to assign blame based on this evidence, as it was not possible back then.

Experiment 2: the students perform a flame test, applying simple concepts of oxidation-reduction processes. By comparing the samples with a library of compounds, students identify certain samples through the color of the flame emitted by each of them (this test reveals that one of the samples is copper sulfate).

Experiment 3: in this experiment, students use a special identifying dye (Dragendorff’s reagent) which is added in small quantities to the solid samples. If the reagent changes its color, it will form a small precipitate, whose color may identify a specific compound. This experiment reveals that one of the samples was an alkaloid (which turned out to be the poison used in our story).

Experiment 4: students perform a very familiar experiment known as “warm foam” or “elephant toothpaste”. If the addition of one of the liquid samples generates the outcome expected within this experiment, it will prove that one of the samples is oxygen peroxide. This activity introduces students to the concept of catalysis.

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Experiment 5: in the experiment “revealing sheet”, when iodine tainted paper sheets are in contact with ascorbic acid (vitamin C), the paper goes back to its original color, demonstrating a redox reaction. This experiment identifies one of the samples as ascorbic acid.

Experiment 6: in the “identifying glue” experiment, if mixing normal white glue with a specific liquid sample results in a new malleable solid, it shows the presence of a Borax solution in one of the samples. This experiment introduces the concept of non-Newtonian mixtures.

Figure 10. Categories of learning takeaways stated by the students to describe “Ethics against Chemistry”

investigation 24.5%	social skills 6.3%	history 18.9%	positive attitude 8.4%	chemistry 44.8%
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These samples were not chosen by chance. Hydrogen peroxide was a common household disinfectant, so it is not a strange element to hold in a house. The presence of ascorbic acid could be explained by the usage of fruit salts that were given to the grandchildren by Maria Carolina. The copper sulfate sample finds its explanation in the storytelling and scenery, as it was used for the roses’ plantation, as a few characters mentioned it. The borax solution also has common household applications.

These experiments were designed to complement the storytelling activity and provide the answer (in part) to the game’s initial question. Students must follow the laboratory protocol to correctly identify all the samples. Several samples can be tested in the process, though the experiment only reveals the composition of one sample. For example, in Experiment 4, two liquid samples are put to the test but only one of them reacts, enabling its identification. In Experiment 6, the liquid sample that reacted in Experiment 4 will react this time with the white glue. This process allows students to proceed through a ‘trial and error’ method, ultimately discarding the samples that show no toxic effect for humans. If they perform this chain of experiments correctly, they should conclude that Experiment 3 revealed the murder weapon. The next step was to suggest who could have better access to such a substance.

RESULTS AND DISCUSSION

In this section, we focus on student feedback on the activity regarding both its storytelling and edutainment components. It intends to analyze the feedback on the suitability of this approach from the student’s perspective. As such, it can be made a case for the positive impact of this framework, proving primary evidence on improving this storytelling adaptation.

The feedback of the students was evaluated with an empirical assessment of the individual reports, voluntarily made by each participant.

Student Evaluation

At the end of the activity, a student evaluation form was embedded in digital inquiries, which prompted them to answer some questions. First, the students were asked to rate the overall experience, on a scale

from 1 to 5 (Likert, 1932), 1 being rated as awful, and 5 as excellent. The participants gave the activity a 4.77 grade (n=160). This represents positive feedback suggesting overall enjoyment in the students.

The following question was intended for 'brain dumping': "Use three words to describe the activity". The results obtained by word analysis from their report answers are depicted in Figure 9. The word cloud portrays common answers from a universe of 406-word entries, amongst a sample of 146 students. The size of the words represents their frequency, therefore words in larger fonts appeared more frequently on the students' answers. Details of this analysis are provided in Table 1 of Appendix 1.

The words in Figure 9 correspond to 62% of the answers given by the students. All of them represent positive feedback from the participants, choosing words that convey educational and emotional answers. The word "mysterious", in our view, cannot be dissociated from the story plot of this activity. The word "different" can be interpreted as describing the novelty factor of this activity since the word "innovative" also appeared (1.5%).

Though the students also used other words in their answers, they were less frequent, and would not be perceptible in a word cloud. Other answers include the words: joy, formidable, original, entertaining, unpredictable, amazing, good, brilliant, and exciting. At the opposite end, the activity was also described as: tiresome, complicated, complex, deceptive, dramatic, stressful, challenging, hard, annoying, and boring. The frequency of these words is also discriminated in Table 1 of Appendix 1.

Finally, one of the questions allowed students to write down their main takeaways from the experience. Only answers that matched these criteria were considered, vague answers like "I learn a lot", "I don't know", "Stuff" or "Everything" were not included, which led to a total of 143 valid answers. The students also gave random answers (14.7%) such as: "one shouldn't kill children", "killing your family is wrong", "be careful who you marry", or even "don't trust medical doctors called Vicente". Answers that truly replied to our question ("What did you learn?") were grouped in the categories in Figure 10.

In the investigation category (24.5%) were included answers regarding the process of investigation included in the game or the skills need to do so, such as: "We should analyze every hypothesis before coming up with an answer"; "Observe every clue", "To be a detective", "To pay attention to details" or "We should think simply and logically instead of creating theories that we cannot prove".

The category of social skills (6.3%) included answers like: "Teamwork", "To judge people better" or "Respect my teammates and everyone's opinion".

The history category included answers that mentioned the history of science and the story of the "Crime on Flores Street", students answered like: "This real case", "Ancient science", "I learned more about forensic chemistry and about history" or "I learned about an historic episode that happened in Portugal".

The positive attitude category (8.4%) includes demonstrations of positive attitudes towards science and chemistry. For example: "I learned that science is very important to help solve cases", "Chemistry is not boring", "I learned that criminology is more important than I thought" or "I learned that I can find the answer to many problems with chemistry".

Lastly, the category chemistry (44.8%), which included experiments, compound identification, and chemical reactions, students gave answers such as: "The reaction of substances with other substances", "Interesting experiences", "More chemical reactions", "I learned that some components are toxic and how to execute some experiments".

Some students gave a more structured answer, which mentioned different aspects; therefore, their answer was included in several categories. For example, the answer "I learned how to act like a 'real' detective and learned a lot about the history of science" was included in the category investigation and in the category history.

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The “Crime on Flores Street” storytelling part made an impact on the students, providing the backbone of this activity. And the activity fulfilled its objective, in that it established a fresh form of edutainment that could help approach difficult subjects, such as chemistry, in a fun and interactive way.

Difficulties in Implementation

One of the major difficulties we encountered was the heterogeneity of each class, composed of children coming from different parts of the country, having different levels of education, behaviors, and knowledge. Although in the 7th and 8th grades Portuguese students have some contact with science, laboratory experiments are often left out, which was proven by the students themselves. Some revealed no previous laboratory training, often failing to identify reagents or laboratory material. Therefore, as the scientific component is a key aspect of this activity, one of the hardships of the activity design was to accommodate adequate experiments to incorporate concepts easily understood by the participants. As we said, since every group of students was heterogeneous, it was challenging to adapt the explanation of concepts during the activity. As to avoid any tedious parts of the activity, teachers frequently needed to adapt their discourse to ensure that the students understood how this content was interlinked with the storytelling elements.

Even though laboratory safety rules are stated by the teacher and also written in their protocols, before any laboratory experiments students often forgot to follow the laboratory rules.

“Ethics against Chemistry” was introduced in the Summer program that lasted a whole day, in a context where learning is supposed to be fun and ‘hardcore evaluation’ is put aside. As such, students might feel more relaxed since they do not have the pressure to succeed, besides that of winning the game. This factor might have reflections on their answers and on their commitment to the task.

On the other hand, one can easily lose the interest of a student or the entire class, unless their sense of curiosity is appealed to and that was not a problem that this activity faced. Much to the contrary, after the initial set of interviews with the Sampaio household, many students started to hypothesize ridiculous explanations for Mário’s death, including an ‘evil twin’, an ‘evil clone’, a ‘suicide’, or even that ‘Berta did it’. We had to repeat for different classes and several times that the students should stick to the information given by the characters and not use external explanations. One frequent question was if the murder would only appear near the end of the story (for suspense building). We had more difficulties in guiding the students through the story, sticking to the important facts, than encouraging them to participate in the activity at all.

Students showed real interest in participating and debating with the teachers and with each other in this case, eagerly explaining who they thought was the murderer. And sometimes the time stipulated for discussion was not enough for all opinions to be heard. Time management for discussion and student participation must be rethought to better compensate time spent on the laboratory stations.

FUTURE RESEARCH DIRECTIONS

“Ethics against Chemistry” was tested for the first time in the Summer of 2019. In this pilot study, the main point was to measure the student’s receptivity, obtain their feedback, and improve this activity for future editions. Evaluation methods still require some improvement, to convey more outtakes from the gathered data.

Further investigation is required, most importantly, to determine if this activity enables long-term knowledge retention. It is important to assess if the children retain the knowledge that they have accumulated, to implement changes that could improve the effectiveness of “Ethics against Chemistry”. It would be relevant to assess if this activity transmits new information or not. The data we provided cannot show if this activity is going to have an impact on students in the long-term. To do so, questionnaires before and after the activity that gauge the student’s chemistry knowledge must be administered. However, the questionnaires must be carefully designed, as too many forms for this age group can be quite plaguy.

Other parameters should also be included in future studies, such as analyzing students’ motivation in relation to the game, as well as science awareness.

Once standardized, “Ethics against Chemistry” could be tested on larger samples and, with the right adaptations, this activity could even be used as a classroom resource for chemistry and history teachings in the 7th and 8th grades in Portugal. If one intends to use this activity in the classroom, major changes should be done, so this activity could be implemented in a 90-minute class.

On the other hand, the model of this activity could be used to inspire similar activities, to tell other stories of forensic chemistry or even stories from other subjects. The combinations of storytelling and gamification are endless, and the results can be very rewarding.

CONCLUSION

Based on the performed evaluation, “Ethics against Chemistry” successfully introduced middle-school children to the history of science topics, in an interesting, interactive, and fun way. Through gamification, storytelling, and role-playing techniques, students adopt the scientific method to solve this game, while learning chemistry concepts with hands-on experiments and solving ethical questions.

This chapter brings new insights regarding the implementation and interpretation of a real-life historical event, in a storytelling-based science communication activity. By combining storytelling methodologies with concepts in chemistry, we have shown that it is possible to connect storytelling with classical disciplines, using new technological channels. The history of science is brought together with the seldom explored storytelling practice, to reveal historical events and convey simple scientific concepts, aimed at middle-school students.

When addressing the edutainment component of the activity presented above, we highlighted its value (and necessity) in the learning process. The feedback gathered from the students showed that their predisposition to learn the outcome of the story (including the scientific themes) was higher when they were engaged with the storytelling feature of the activity. It was perhaps the “entertainment” component that sparked their interest in learning what was happening in the story. Clearly, the connection of edutainment with the learning process cannot be overlooked, as it can be a key factor in increasing student motivation.

This game establishes a great framework for exploring other topics regarding the history of science and STEM, while discussing some ethical issues effectively. By replicating the design and structuring steps made available throughout this chapter, scientists, teachers, and science communications have a valuable tool to create or adapt stories for science education purposes.

The use of a real-life event from the history of science and the location of this event (Porto, Portugal), contributed to an easier connection with the audience (Portuguese students). Also, it allowed them to assimilate the importance of the history of science, its overall development, and how it can explain so

much of the science applications of our daily life. Therefore, it was a major contributor to the increase of students' awareness of science during this event.

ACKNOWLEDGMENT

- The authors would like to thank Professor Carla Morais for logistic support during our activity, and Professor João Paiva for his full support and incentives for this project.
 - José Ferraz-Caetano thanks Fundação para a Ciência e Tecnologia (Portugal) for program fund UIDB/50006/2020 and PTDC/QUI-QIN/30649/2017 to REQUIMTE-LAQV.

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KEY TERMS AND DEFINITIONS

Edutainment: Conjugation of an entertainment activity with educational content, so as to improve learning and make it more interactive.

Gamification: Adding game elements to a non-gaming context, such as team-players competitiveness, win/lose logic, or gaining points through the activity.

Hands-on Activity: A type of experimental activity that invites the touch sensitivity of the participant, who can manipulate objects.

Non-Formal Education: Learning activities provided outside the school system (formal education).

Problem-Based Learning: Learning technique that appeals to the students' curiosity by establishing a problem to be resolved, and by doing so, the students learn from this task.

Storytelling: The art of telling a story in such a way that it compels the audience, engaging with them through appeal to the emotional side. A good resource to use in science communication.

APPENDIX 1

All answers to the question “Use three words to describe the activity” were carefully analyzed and the ones that did not meet these criteria were eliminated (like “I should have won”), resulting in a sample of 146 valid answers. Similar words were uniformized, for example, “mysterious” and “mystery”, those answers were counted as “mysterious”, the same goes for “cultural” and “culture” that were counted as “cultural”, “challenge” and “challenging”, counted as “challenging”. Words with related meanings were not merged in purpose, so as to stay true to the students’ answers.

For the word assessment frequency, answers that were a repetition of one word (“cool, cool, cool”), were counted one time, rather than three times. Answers that present two different words (“fun and creative”) or just one (“good”) were also included in the analysis.

Finally, the words were translated into English, always trying to be true to the Portuguese meaning.

Table 1. Groups of words that the students used to describe “Ethics against Chemistry”, divided by percentage (free translation by the authors)

Percentage	Words
0.25	Suitable, Joy, Animated, Anxiety, Brilliant, Tiresome, Captivating, Climatic, Neat, Uninteresting, Determined, Dramatic, Entrepreneur, Deceptive, Enriching, Tedious, Entertaining, Involving, Amazing, Stimulating, Excellent, Experimental, Explosive, Easy, Cute, Formidable, Delightful, Informative, Intelligent, Exchange, Nice, Logical, Crazy, Liar, Observative, Obvious, Original, Great, Patient, Controversial, Laughter, Simple, Stressful, Sad, Annoying, Exciting.
0.49	Scientific, Complex, Complicated, Confusing, Dynamic, Weird, Happy, Objective, Thoughtful, Chemical, Repeatable, Thriller, Top.
0.74	Cultural, Spectacular, Unpredictable, Boring.
0.99	Good, Challenging, Thrilling, Amusing, Enthusiasm.
1.23	Incredible, Interactive, Surprise.
1.48	Hard, Innovative.
1.72	Fantastic.
1.97	Creative, Curious.
2.46	Different, Intriguing.
4.19	Mysterious.
4.43	Educational.
7.39	Cool.
18.97	Interesting.
22.17	Fun.