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Watering the Lava Flow: The Use of Comics in Communicating Scientific Information about Water Conservation

Introduction

Water scarcity is one of the main concerns in Mexico City (Dominguez, 2006). About one-quarter of its inhabitants do not receive enough drinking water in their homes to satisfy their basic needs. Fifteen percent of the population do not receive water on a daily basis and nearly two million depend on water trucks (EFE, 2021). The prospect for increasing water resources is virtually non-existent as there is a serious hydric imbalance in Mexico City: water is extracted at more than double the rate than what is recharged into local aquifers and about one-third of the water supply is lost to leaks (Breña Pujol y Breña Naranjo, 2009).

The main campus of the National University of Mexico is located in the south of Mexico City and occupies nearly 740 hectares. About eighty-eight litres of water per second are extracted from local wells for different uses, one of which is the irrigation of one hundred hectares of gardens. A total of twenty-two litres per second are used for this purpose (PUMAGUA, 2013), and this water is used in an inefficient way (PUMAGUA, 2012).

Most of the areas of the campus currently planted with grass were originally covered by a xerophytic and thornshrub ecosystem (Figure 1) with an outstanding biodiversity and landscape value (Lot & Camarena, 2009). As a matter of fact, scattered along the campus there are still about forty hectares of this original vegetation (Zambrano et al., 2019). This kind of vegetation has many environmental advantages, such as no need for irrigation and little maintenance requirements (Lot & Camarena, 2009).

We decided to disseminate water saving irrigation practices, including both grass watering and substitution of grass with native vegetation, as part of a water management program within the university. In connection with this project, we created a narrative that included relevant information to be addressed to the university community in general. Our justification for doing this was a widespread lack of awareness about these matters that was established previous informal surveys carried out by UNAM's students.

The suitability of using art-based methods in sustainability research has been widely discussed by Heinrichs and Kagan (2019) as a way of "grasp-

ing with novel methods the corporal-sensorial affective dimensions of human action in routinized socio-material practices, and allow[ing] for new imaginative processes". These authors emphasise the importance of art in mobilising emotions, intuitions, the subconscious, and tacit knowing. Art-based methods also allow research into the area between the known and the unknown, while respecting ambiguity. Similarly, in their article about communication of ecological information through artistic expressions, Curtis et al. (2012) point out how art promotes new ways of regarding ecological issues, how it touches emotions, and can even create a festive mood.

Narratives, as a form of art, can be defined as "a particular structure that describes the cause-and-effect relationships between events that take place over a particular period that impact particular characters" (Dahlstrom, 2014). The aim of narratives is to explain a series of caus-ally linked events that unfold over time (Norris et al., 2005). They are a useful tool to represent and communicate knowledge for the fol-lowing reasons among others: people are familiar with the narrative format of communication (Negrete, 2009; Yang & Hobbs, 2020), and narratives are an effective emotional detonator, a long-term mnemon-ic structure, and an important reinforcement for learning (Negrete, 2020; Negrete, 2021)

Comic strips (the longer forms known as graphic novels) are a form of narrative with a proven success in science education and communica-tion (Tatalovic, 2009). This is because text and illustrations presented together work well to improve learning (Hosler & Boomer, 2011) as they induce the use of several parts of the brain (McCloud, 1993). They are also a form of narrative enjoyed by a significant part of the popu-lation. Since 2009, over 950 million comic book units have been sold globally, which account for 13.5% of total book sales during this period (Curcic, 2023).

Mexico is a country with poor reading habits. In 2021, about 70% of the literate population read "something" (books, magazines, newspapers, or internet page) (Varela, 2021). Less than 40% read a book during the year prior to the survey, the majority of whom were people with at least secondary school education (Instituto Nacional de Estadística y Geografía, 2022). Furthermore, the main reason for reading is enter-

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Figure 1: Vegetation of the Ecological Reserve of El Pedregal de San Angel, UNAM (source Reserva Ecológica del Pedregal de San Angel)

tainment. For instance, in 2002, nearly twenty million entertainment magazines, including comic strips, were sold in Mexico (Chavez Mendez, 2005). The fact that comic strips appeal to a broad sector of the Mexican population makes them a very promising medium for environmental communication.

Many studies have been undertaken about the impact of narrative communication, including one by Golding et al. (1992), who carried out an experiment in order to test the hypothesis that individuals respond better to risk communication via narratives than technical information. Likewise, Negrete and Lartigue (2004) measured the effectiveness of learning tasks when scientific information is included in a short story compared with when it is conveyed through a traditional factual text. Betsch et al. (2013) compared the effect of narrative and statistical information about vaccine-adverse events on vaccination decision, and Yang and Hobbs (2020) compared the effectiveness of using factual texts versus narrative information to communicate with consumers about a new biotechnology application. All of these studies found that narratives were more effective than factual/technical information.

In contrast, very few studies address the effectiveness of comics to convey scientific information (Farinella, 2018). For instance, Hosler and Boomer (2011) found that an improvement in attitudes about biology was correlated to attitudes about comics, suggesting that this type of narrative may have contributed to shaping student attitudes in a positive way. In a similar study, Weitkamp and Burnet, (2007) created a comic strip that was presented to primary school students. The authors of this study found out that students were able to give scientific explanations based on the information provided in the comic strip. Lin et al. (2015) compared the effectiveness of a comic book and a text booklet about nanotechnology. They discovered that both instruments were effective in terms of conveying information and improving attitudes towards the subject. However, the comic book increased pupils' interest and enjoyment of learning while the opposite happened with the text booklet.

Literature about the impact of comics in environmental communication and education is scarce. Richter et al. (2015) conducted one such study in which the authors used comic strips to convey information to primary school students about nature conservation and sustainable development. They discovered a significant positive effect of this narrative on knowledge acquisition.

Hands et al. (2018) investigated the influence of an educational comic strip on the future gardening intentions of urban residents. Although the authors discovered that the narrative had a positive effect on future plant choice of respondents, they also found that the response was not generalised. Therefore, they conclude that comics should be used in conjunction with other instruments.

Regarding the use of comics to encourage water conservation, Houben (2019) created a comic strip about the importance of groundwater addressed to Paraguayan primary school students. Although he was not able to quantitatively measure the impact of the illustrated narrative on children's knowledge and attitudes, teachers that presented the comic strip to their students received interesting feedback which led to the following interesting recommendations: 1) Use positive characters with which children can identify. 2) Use negative characters to personify environmental problems. 3) Do not forget fun and suspense. 4) Use landscapes, buildings, plants, and animals of the country or region in

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which you are working. This will enhance identification with the story. 5) A happy ending is necessary, such that the problems presented are brought to a successful conclusion, which is best achieved through the actions of the main characters themselves.

This paper presents our findings in the construction and evaluation of a comic strip about water saving gardening practices. In this first exploratory stage of the project, the comic strip was presented to a sample of UNAM's students. In terms of literary genre, we chose to write a detective story because this genre captures the reader's attention through an intriguing plotline. As Baps (2020) states: "It is a combination of curiosity into the darker side of humanity that influences our general interest into crimes and murder mysteries. Our brains want to connect pieces together to solve the puzzle innately."

In order to assess the effectiveness of our comic strip in conveying environmental information, we used the RIRC method (Negrete & Lartigue, 2010). Specifically, this method was designed to assess the retention and comprehension of information by using four independent memory tasks: recall, identify, retell, and contextualise (the acronym corresponding to the first letter of each task). The input of the RIRC method consists of a qualitative complex stimulus, such as a narrative or another text format and the outcome is measured through a questionnaire.

Method

Identifying the information to be communicated

As part of the activities of the water management program, we carried out several workshops, in which forty-five gardeners from the main campus of UNAM participated. The aim of these workshops was to learn about their gardening practices, specifically their irrigation methods and their perceptions of native vegetation. Among other things, we found that there were no clear criteria for deciding how much water to use in the different areas of the campus. In addition, we learned that although they expressed a positive opinion about native plants, only half of them were interested in replacing the grass with this kind of vegetation. Consequently, we decided to include the following two key issues in the comic strip:

A simple method for knowing when plants are overwatered is to take a handful of soil, and, if it immediately breaks down, it means that the soil is overwatered.

Important benefits of native vegetation of the campus include that it survives on rain water and has low maintenance requirements.

Creation of the comic book (Appendix I)

In the abovementioned workshops, gardeners frequently mentioned that they perceived a lack of respect for their work from the community. People constantly walked through the areas where they worked, damaging the grass, while also demanding that the grass be green all year round. We concluded that it would be worthwhile to make their work visible, while also communicating information about gardening water saving practices.

Under our supervision, several students participating in the water management program were tasked with creating the story and making the drawings. To make the comic appealing to the audience, we decided to write a detective story. These kinds of texts, at least in their Mexican variants, tend to include some amount of violence, a practice to which we yielded but only to a modest degree.

To highlight the environmental information we wanted to convey, we attempted to present a simple conflict, a straightforward resolution, and include only a few characters. Also, we decided to leave a third of the images without text to give the reader breathing space, and when texts were present, we kept them short. Likewise, we tried to make sure that the images were attractive but did not overshadow the text. In this way, we hoped to enhance the reader's interest in the story.

Due to the fact that we opted for a detective story, which, as mentioned above, typically includes some violence, and that it took place in the main campus of UNAM, where lots of people walk from one place to another, we thought it was important not to alarm the readers. Therefore, we introduced characters far from reality, in particular, the burglar and the detective. We believed that this would establish a certain distance between the audience and the story.

In contrast, due to our interest in making the gardeners' work visible, we opted to depict them as cooperative, proud of their job, and knowledgeable. In this sense, the information that we actually wanted to disseminate was already known by the gardeners of our story. The bad practice of some of the gardeners that is frequently detected by the community of UNAM (e.g. irrigating for long periods or placing sprinklers in the wrong places) were pointed out in the comic as something alien to them.

The following is a summary of the story. While walking by the gardens of UNAM's main campus, a young girl's purse is stolen by a mysterious man. The girl is in shock and cannot give a statement. The police call a detective who carries out an in-situ investigation. He visits the crime scene, and asks a gardener if he has seen anyone suspicious. The gardener answers that he has indeed witnessed suspicious activity, by which he means that the gardens are being excessively watered, something that is unusual in their working area. Consequently, he is sure that someone not in the crew is pretending to be a gardener. The detective visits other areas in which there is native vegetation and the gardeners tell him the advantages of these kinds of plants. Finally, they set up a trap for the burglar, which leads to his capture.

Evaluation of the understanding and retention of environmental information

We carried out a survey in one of the main green areas of the campus, an area visited by people from several schools nearby. Through a random sampling, we approached individuals and selected those who were students of UNAM. Those that voluntarily agreed to participate in our study were asked to read the comic strip and then answer a written questionnaire with eight questions (Appendix II), two for each task, according to the specifications of the RIRC method.

Both explicit and implicit memory were evaluated. Explicit memory was measured through three basic tasks: declarative knowledge, recognition, and recall. Implicit memory was assessed through procedural knowledge. Table 1 shows the description of each task, as well as the type of question used for this purpose.

Table 1: Tasks for measuring implicit and explicit memory

Task	Description	Type of question
Explicit memory		
Identify	Select or otherwise identify an item as being one that you learned previously.	Multiple choice
Recall	Produce a fact, a word, or other item from memory.	Fill in the blank
Retell	Repeat the items on a list in any order in which you can retell them.	Open-ended question
Implicit memory		
Contextualize	Remember learned skills and automatic behaviours rather than facts.	Open-ended question

First, we carried out a pilot survey in which seventy-eight questionnaires were used in order to assess the reliability, or internal consistency of the instrument. We measured the Cronbach alpha coefficient and found that our questionnaire had good reliability ($\alpha = 0.83$). Therefore, we used 195 more questionnaires, bringing us to a total of 273.

Results and discussion

Our main findings are summarized in Table 2 and Figure 2. As they both show, in terms of the percentage of correct answers, the comic strip proved to be an effective means of communicating information about water conservation practices. Although there is room for improvement, the average of correct answers for the eight questions is a passing grade (64%). It should also be noted that performance was particularly high for two questions (1 and 5), while performance for questions 3 and 6 tended to be low.

Table 2: Percentage of correct answers for the different memory tasks

Question	Correct or partially correct answers (%)	Incorrect answers (%)
Identify		
1. When a handful of soil breaks down easily, it can be due to...	89	11
2. What do grass and native plants of El Pedregal need to survive?	62	38
Retell		
3. Overwatering is not a good idea for...	44	56
4. What are the benefits of having native plants of El Pedregal in our campus?	87	13
Recall		
5. For how long should the gardens of our campus be watered?	58	42
6. What happens if they are watered for longer periods?	46	54
Contextualise		
7. If you lived in a city where water is scarce and your house had a big garden, which actions of the Impostor presented in the comic book would you carry out in order to decrease water consumption in irrigation?	65	35
8. How would you know if you were using too much water in irrigation?	58	42

Percentage of Correct Answers
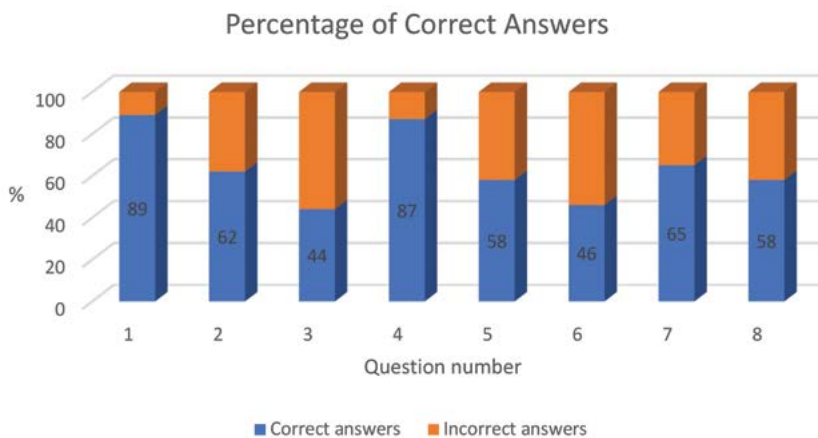
Figure 2: Percentage of correct answers for all the questions

As Table 2 and Figure 2 show, most of the answers were correct or partially correct (at least one or two correct answers were provided for questions with several correct answers). However, there were also two questions (a *retell* and a *recall* one) in which the number of incorrect answers was higher than the number of correct ones. Perhaps this was due to the fact that those two questions were not specific enough or perhaps even ambiguous ("What happens if plants are watered for longer periods?", and "Overwatering is not a good idea for ___"). Likewise, the average percentage of correct answers for the whole questionnaire was 64, which corresponds to a passing grade, but leaves plenty of room for improvement.

It is worth pointing out that the two questions with the highest number of correct answers ("When a handful of soil breaks down easily, it can be due to ___", and "For how long should gardens of our campus be watered?") were those with only one possible correct answer. Participants had a better performance in these questions than in those that had several possible correct answers, even when we considered it correct when only one was provided.

It is interesting to note that the participants' performance did not correspond to the degree of complexity of each memory task. In other words, *identify* did not show a better performance than *recall*, or *re-*

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call than *retell*, and so forth. Apparently, performance is related to the kind of questions presented and perhaps to other aspects, such as the place within the comic book where the information is located. For instance, the answer of one of the questions with a good performance is located almost at the beginning of the comic book. It is one of the first scientific facts provided, while another scientific fact that was frequently remembered was placed at the end of the comic strip.

Likewise, the two questions with the highest performance referred to information that was accompanied by images in the comic book. This finding is backed by the study of Houts et al. (2006) in which it was determined that images closely linked to text can, when compared to text alone, significantly increase attention and recall of health education information. In future studies, it would be interesting to test whether these two factors (location within the narrative and linking of images and texts) are indeed determinant for participants' performance.

One of the main challenges in the creation of *The Impostor* was to write a story that captured the readers' attention. Therefore, a significant part of its beginning consists only of the plot of the detective story. Nevertheless, it was also our aim to provide a considerable number of scientific facts, as well as information to enhance the image of gardeners. In addition, we needed to keep the narrative short in order to avoid losing the readers' interest. All of these requirements may have resulted in an excessive concentration of scientific information in the middle part of the story. In future projects, it would be worthwhile trying to distribute this information throughout the comic book in a more balanced way.

It is worth mentioning that many of the characteristics of our comic strip were derived from recommendations made by Houben (2019): specifically, the use of suspense; the presence of positive characters that the reader may identify with (environmentally responsible gardeners), and of negative characters to represent bad environmental practices (the thief); the depiction of landscapes with which readers are familiar (different places on the main campus of UNAM), and; a happy ending achieved by the actions of the characters (in the end, the thief is caught by the detective).

In the near future, we would like to test *The Impostor* using a sample of gardeners as well as with other members of the university community, such as lecturers, researcher, and university authorities, in order to compare our results with those of this study.

Looked at from a wider perspective, this paper contributes to art-based research. As Heinrichs and Kagan (2019) point out, although the importance of paradigmatic methods of communication have been recognised, environmental challenges "are overwhelmingly approached in sustainability science through normative, discursive, textualist, mentalist ways, and through an excessive narrowing-down of possibilities in the solutions-orientation." Our work might contribute to emphasising the enhancement of sensorial experience, cognitive evaluation, and imagination provided by artistic works, which would encourage engagement on sustainable development. Furthermore, the plot of *The Impostor* could be represented through other media, such as an audiobook or a video. It would be interesting to assess the impact of alternative sensory experiences on the effectiveness of science information communication.

Conclusions

As a whole, we believe that the comic strip *The Impostor* represents an interesting and successful communication material that could help to enhance better irrigation practices and to encourage more respectful attitudes towards native vegetation conservation as well as gardeners' everyday labour.

This work reveals interesting facts, such as the importance of where scientific information is placed within the comic strip, the need for spreading the information out in order to enable the reader to process the information acquired, and reinforcing the idea that images are helpful aids for memory performance. But undoubtedly, the use of narratives and other artistic works has the potential to encourage responsible water practices.

Acknowledgements

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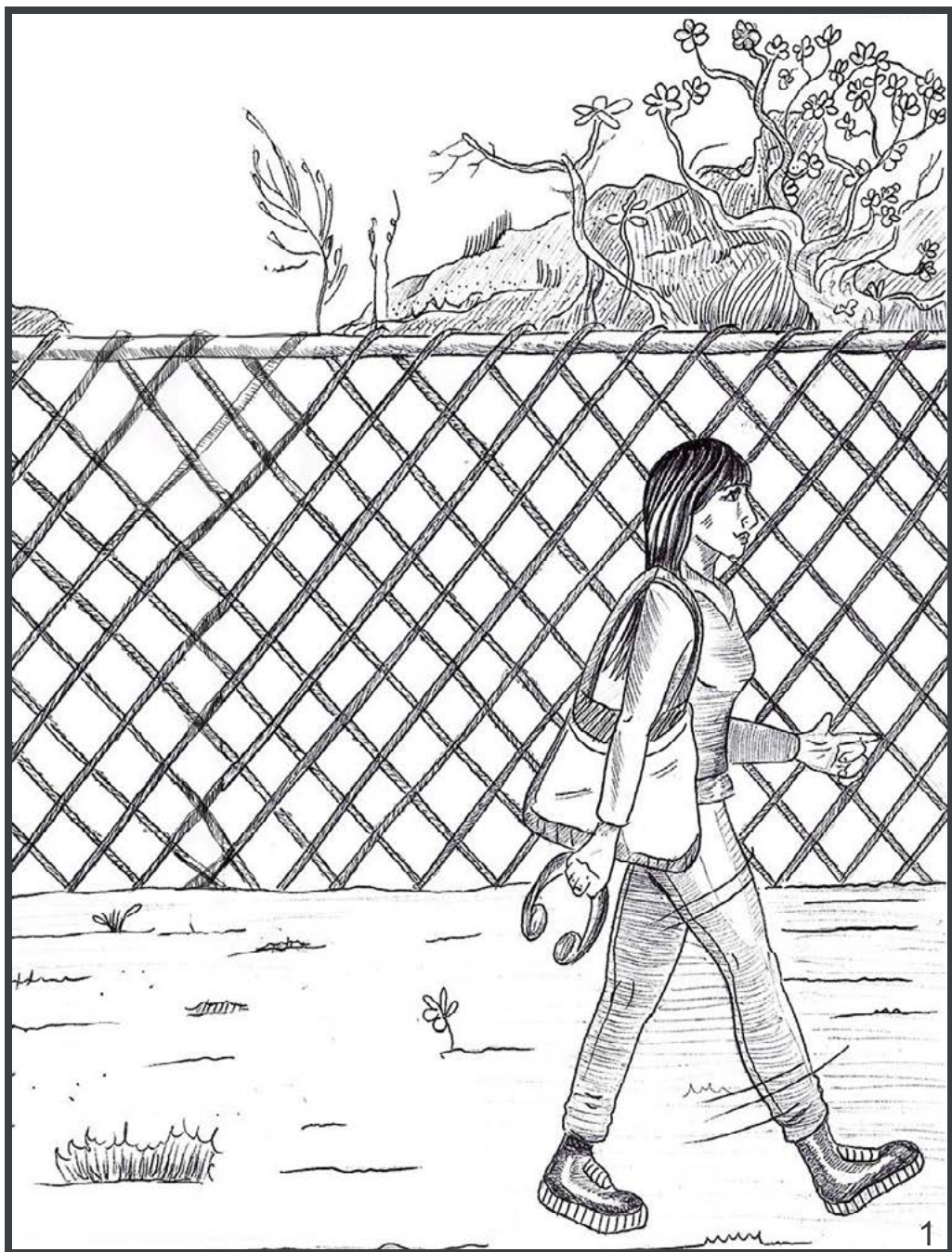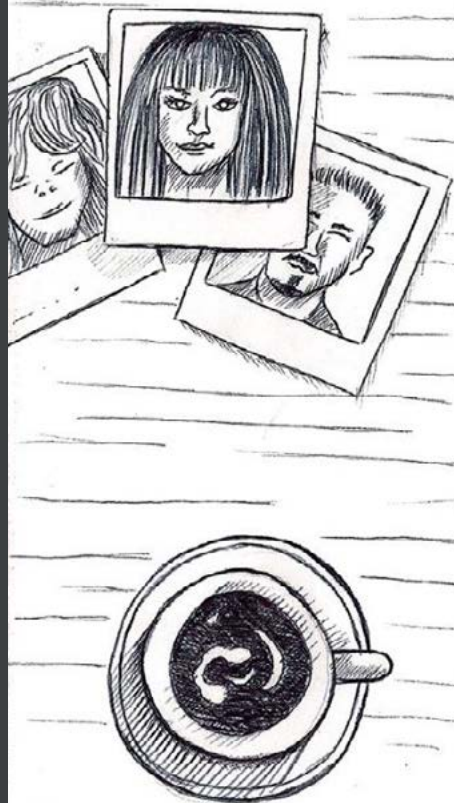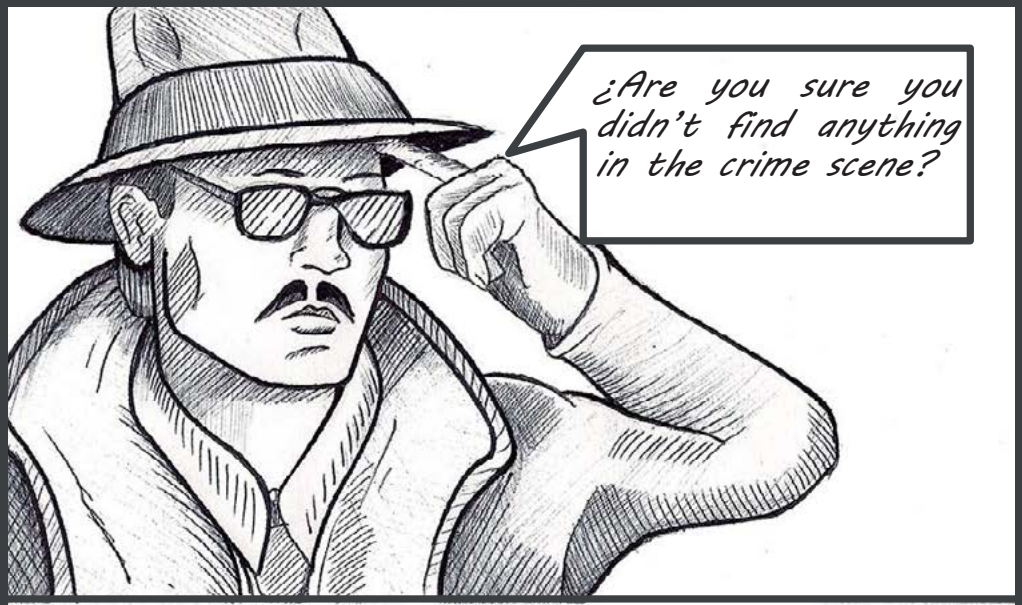
Appendix I

The impostor
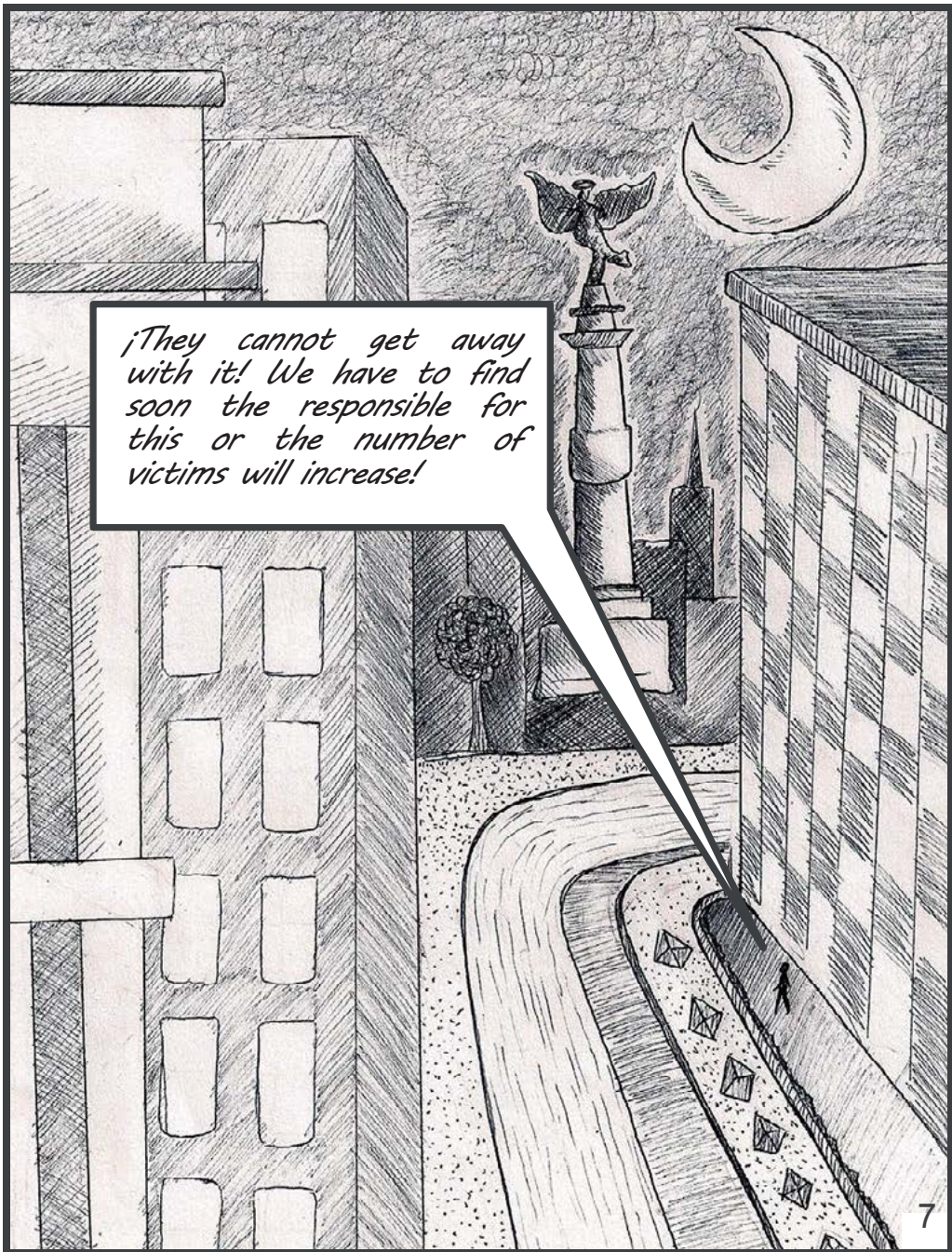
¡They cannot get away with it! We have to find soon the responsible for this or the number of victims will increase!

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The agent is hard at work in the restless search for data that could help find the perpetrator.

I have searched the place hundreds of times and nothing! This scumbag is going to defeat us and will go free per our fault!
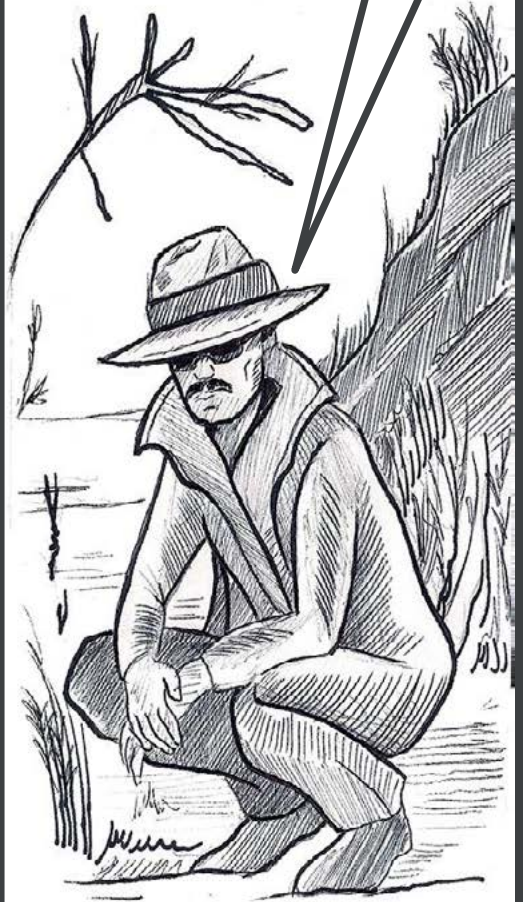
Perhaps you are looking for the wrong leads, inspector

I´ve seen you wondering around for hours, unable to find answers.

Who is there?

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Let me introduce you to the officer who is investigating the crimes committed in this area.

We've noticed that someone is wasting water, this person is leaving aspersers on during midday, even watering the asphalt areas.

And how do you know all this?

I told you, we are expert gardeners!
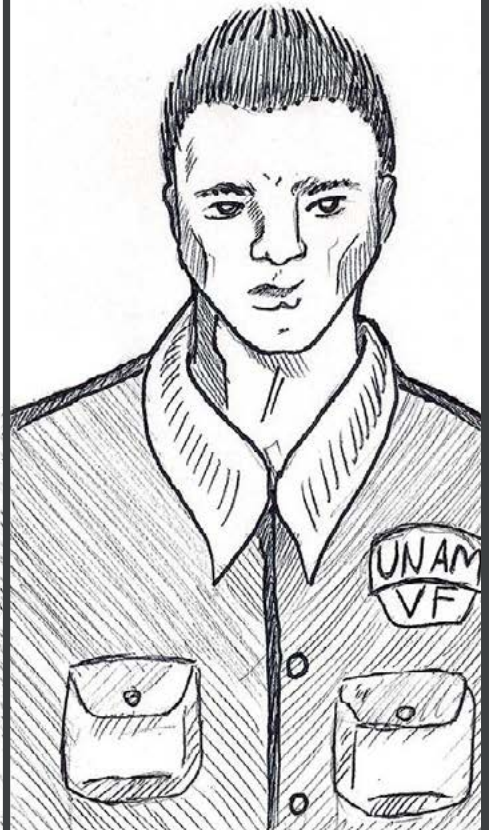
Listen, there has been soil and climate studies and, taking that into account, it's known that here we have to water plants for half an hour, otherwise the soil gets saturated and water drains underground

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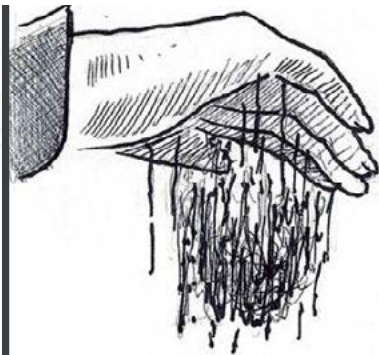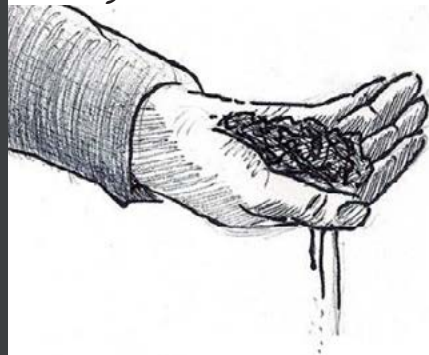
Gardens with native plants only need maintenance, no watering is needed.
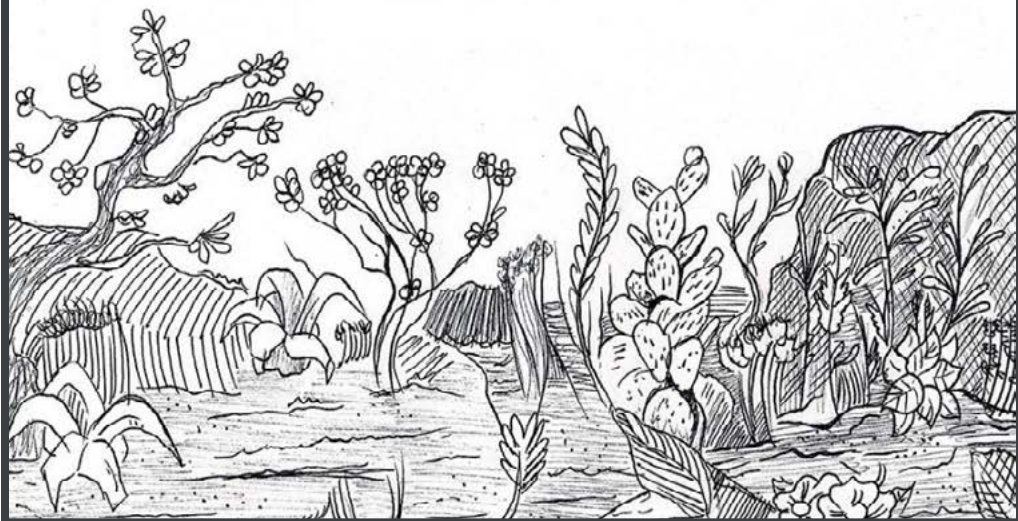
Grass gardens require watering and maintenance.
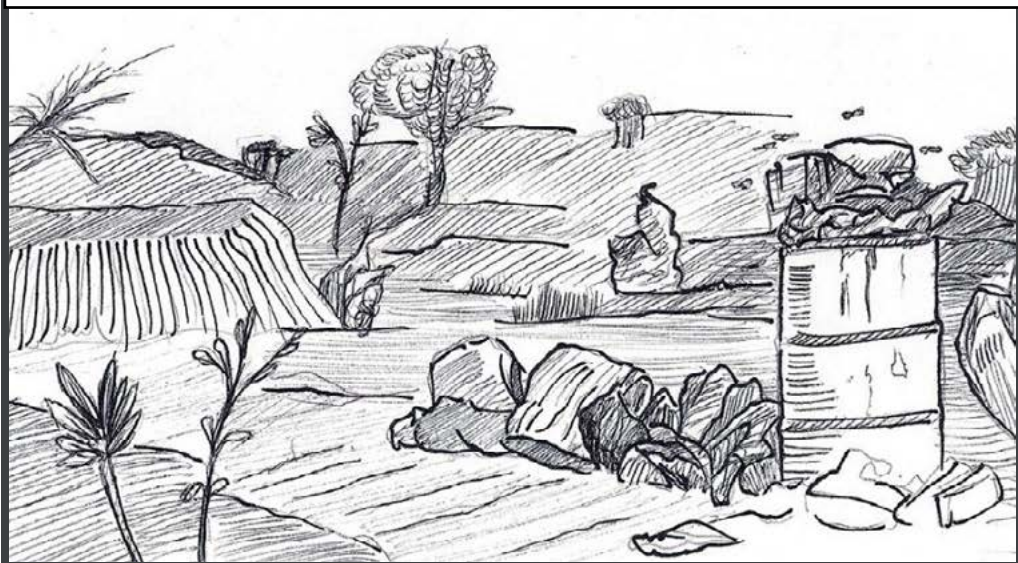
That is why we give our full effort to maintain this place.

Here someone is doing everything wrong and we are going to find him.

And there aren't new workers that can make these mistakes?

When new employees are hired we always supervise them.

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Several of our fellow workers have seen a man dressed as gardener that they are unable to recognise but when they try to approach him, he always runs away.

It is clear that the criminal is hiding on the premises, pretending to be a gardener to pass unnoticed and commit his atrocities!
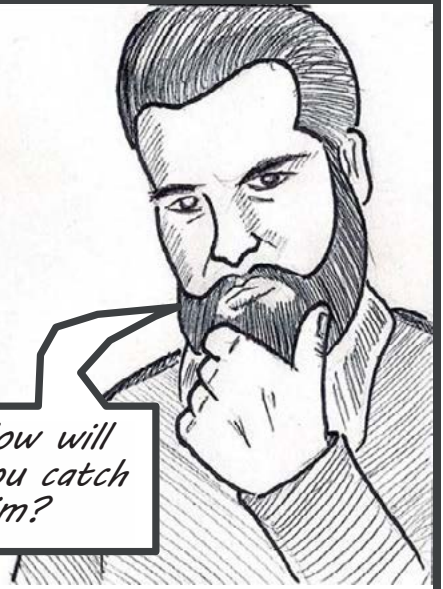
How will you catch him?

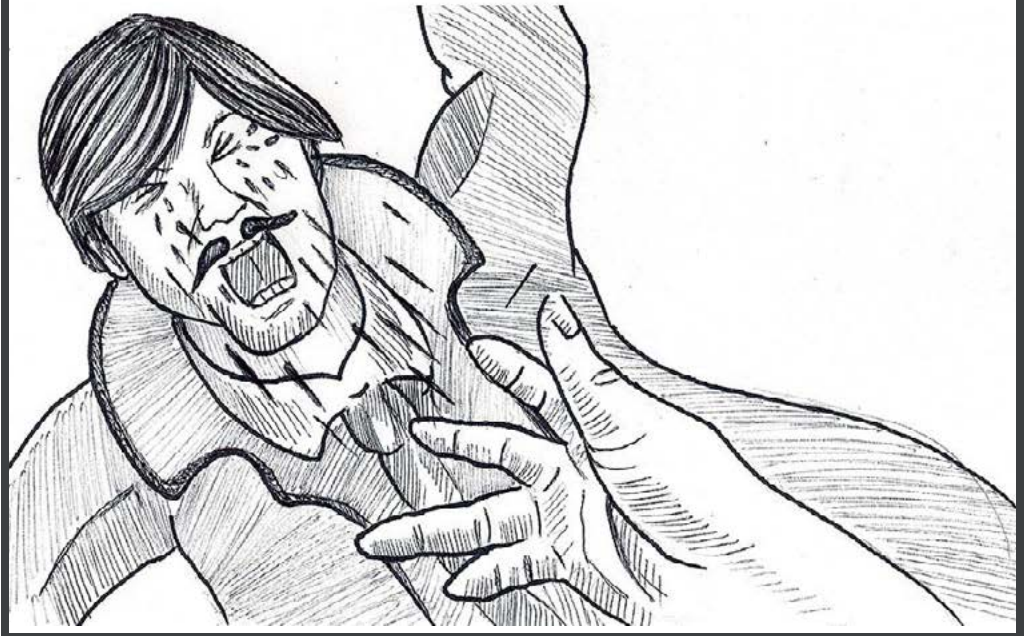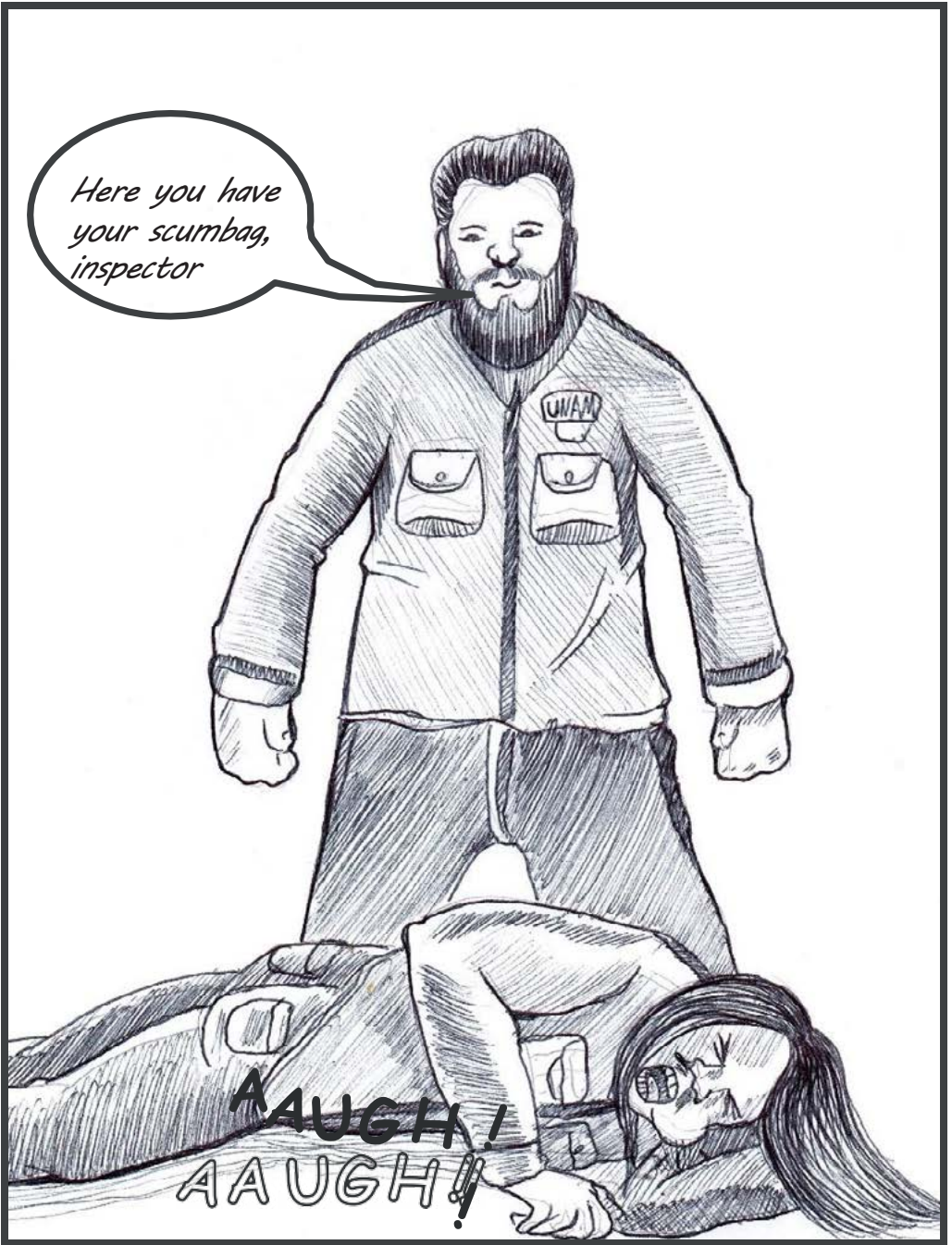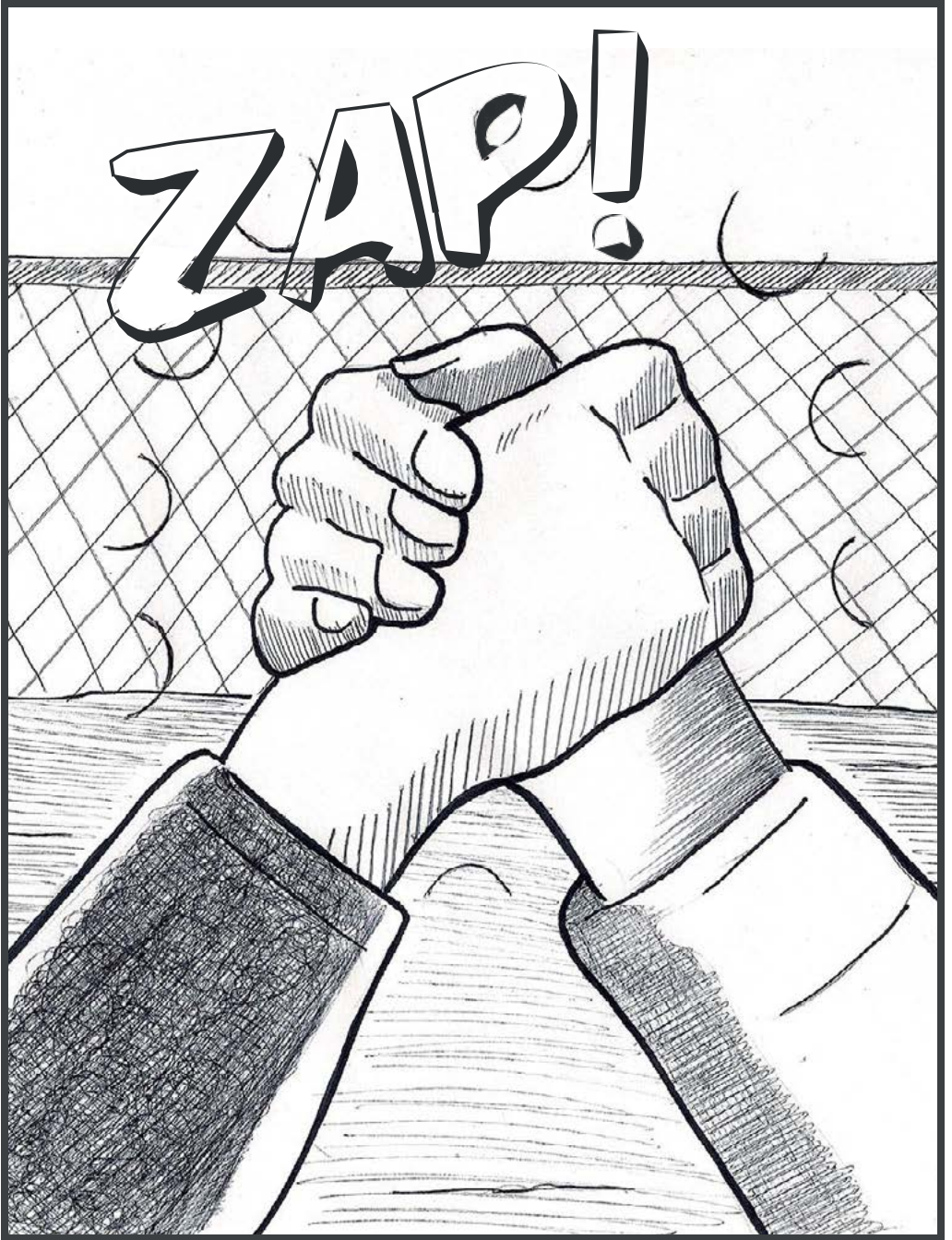I think I have a plan, but we need your help.

21
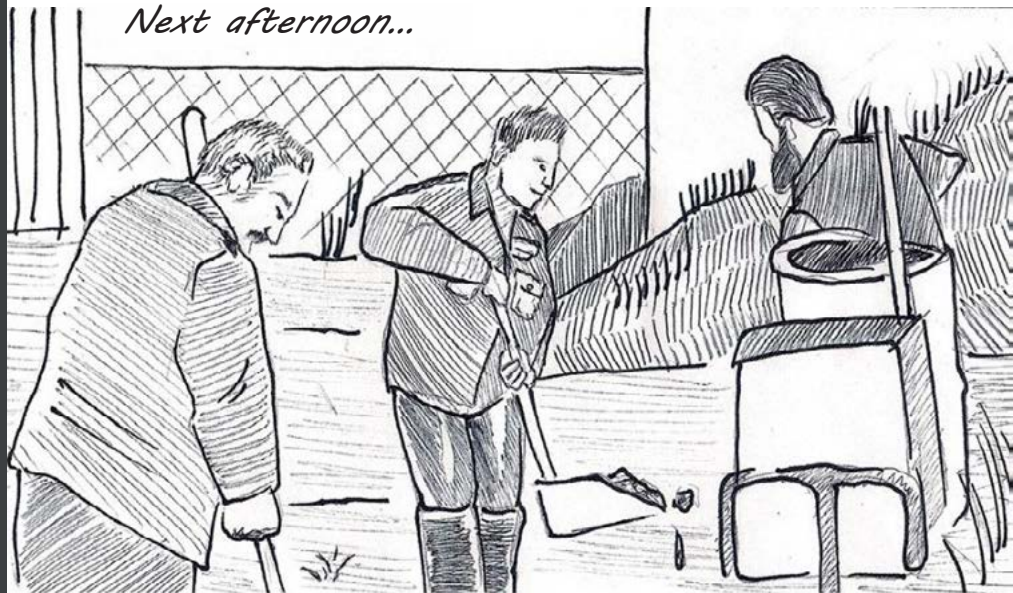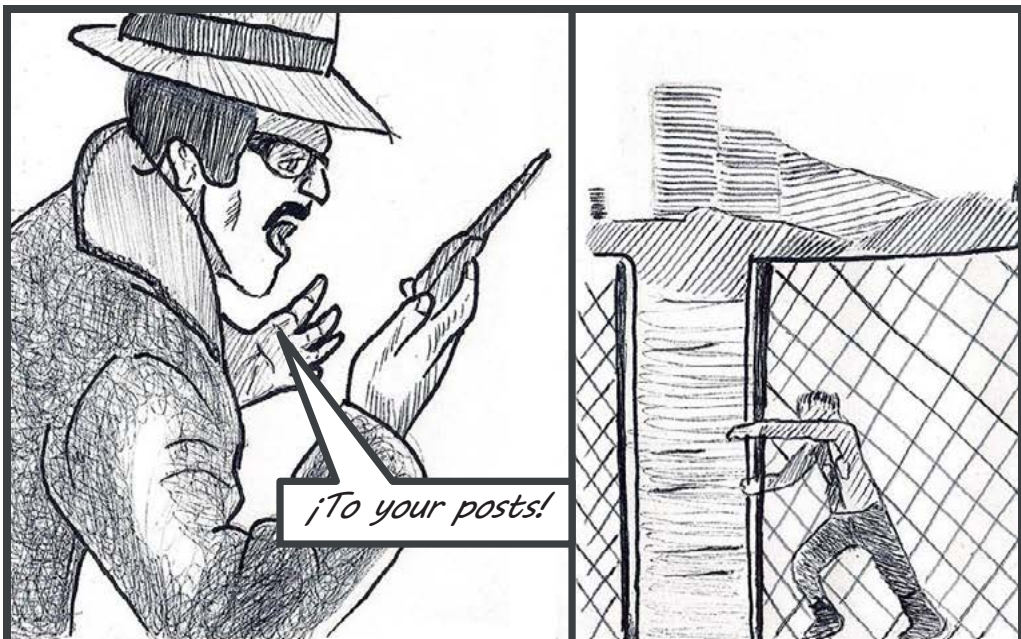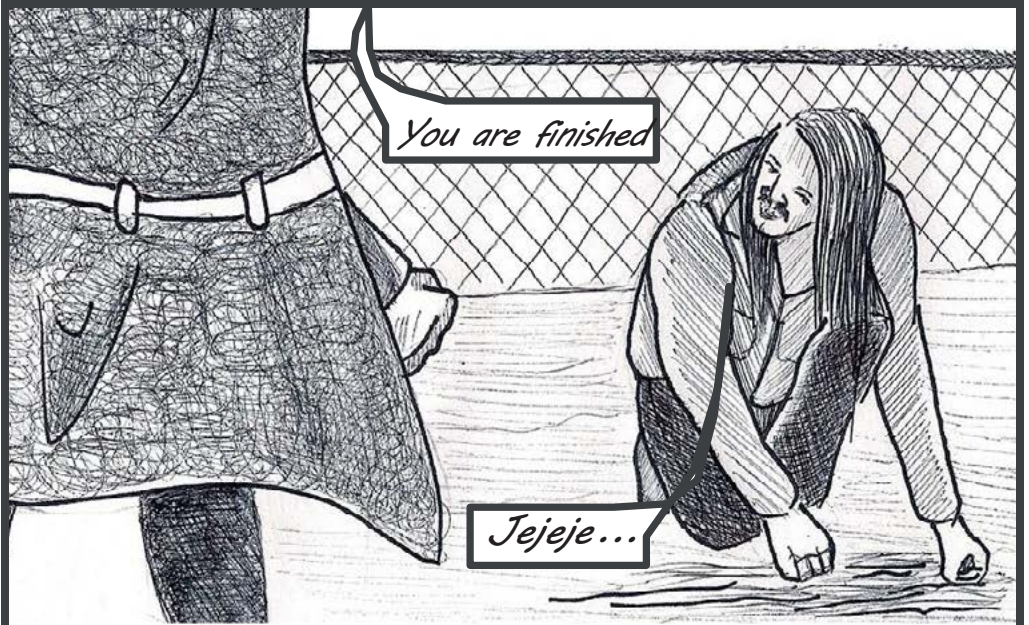
Sometime latter...

That is how with the help of my crew and the inspector we were able to catch the criminal.

Impressive! And now we can be safe here and enjoy the place.

Yes, but we have to continue acting to preserve the biodiversity of this place, saving the water that we will need.

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Appendix II

Questionnaire

1. When a handful of soil breaks down easily, it can be due to…
a) The water that it contains is polluted.
b) It has too much water.
c) It lacks water.
d) The soil is not good.

2. What do grass and native plants of *El Pedregal* need to survive?
a) Grass: watering and maintenance; native plants: maintenance
b) Grass: watering; native plants: maintenance
c) Grass: maintenance; native plants: watering
d) Grass: watering and maintenance; native plants: watering

3. Overwatering is not a good idea for: water conservation and plants.

4. What are the benefits of having native plants of *El Pedregal* in our campus? They preserve the local ecosystem as well as help in saving water.

5. For how long should gardens of our campus be irrigated? For no more than half an hour.

6. What happens if they are irrigated for longer periods? The soil gets saturated and water. drains.

7. If you lived in a city where water is scarce and your house had a big garden, which actions of those presented in the comic book The Impostor would you carry out to decrease water consumption in irrigation? I would substitute plants with high water demand for native plants.

8. How would you know if you are using too much water in irrigation? I would take a handful of soil and see if it breaked down, which would mean that it was oversaturated with water.