Storytelling with Chemistry and Related Hands-On Activities: Informal Learning Experiences To Prevent “Chemophobia” and Promote Young Children’s Scientific Literacy

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**ABSTRACT:** The dissemination of chemistry has been experienced as a difficult task, largely because of the negative image that the public has of this science, but also because of its inherent complexity and its own semantics and symbolism. Science centers, as informal learning environments, can contribute to a more effective dissemination of chemistry to an audience of all ages. This article describes a study that took place in “ROMULO—Centro Ciência Viva da Universidade de Coimbra”, which involved a convenience sampling of 29 students (ages 8–10) from an elementary school. The experiment included storytelling (covering concepts of chemistry) followed by hands-on activities emulating the story. After the hands-on activities, the students were asked to express, through drawing, what they felt to be the most relevant aspects of what they experienced. Students’ drawings have shown that they enjoyed the whole experience, with an emphasis on the storytelling, the hands-on activities, or a combination of both. In the future, we plan to assess in a more systematic manner the impact of the storytelling on learning and development of scientific literacy, as well as the impact on the way young students perceive chemistry.

**KEYWORDS:** Elementary/Middle School Science, Public Understanding/Outreach, Hands-On Learning/Manipulatives, Textbooks/Reference Books, Applications of Chemistry, Descriptive Chemistry

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He is grown-up, not young, often bald, strictly male, often a chemist, wearing odd clothes and working on mysterious things, conducting projects which sometimes help save the world, sometimes harm our natural environment. He lives and works - often into the small hours - in a grey laboratory, alone, no colleagues, utterly isolated from the outside world. His “space” looks like a laboratory equipped with test tubes, with reactive substances but also magic potions; mostly a windowless space, and any windows there are have iron bars.

Some authors suggest that a child’s outlook on science, fairly deep-rooted from as early as 9 or 10 years of age (and surprisingly unchanged by the time these kids reach secondary school), may have an impact on their future career choices. Although children might not yet have developed chemophobia as many of their adult teachers and parents might have, there is clear evidence in the literature stating that children show negative perceptions of science, in general, and chemistry, in particular. Thus, more than emphasize chemophobia in children, we wish to stress the need that, from an early age, students be given an antidote, because they are integrated into a society that frequently has a negative view on chemistry. This connotation of chemistry, often pejorative, is partly the result of the intersection of the history of science and the history of mankind. Despite the enthusiasm surrounding the achievements of chemistry during 19th and early 20th centuries, public opinion on this science appears to have been more influenced by the First World War, often referred to as “Chemist’s War”,...
when the use of dynamite, explosives, and poison gas contributed to a terrible turning point in civilization. During the 20th century other controversial issues followed, causing lasting damage to the reputation of this science. Ironically, it should be noted that it is chemistry itself that investigates and prevents some of its potential dangers.

The dissemination of chemistry in modern societies, trying to balance the historical association with “chemophobia” with the dependence on the products made possible by this science, is challenging and complex. In this context, it should be noted that there are several unexplored ways of pursuing a more effective dissemination of chemistry to the public in informal learning environments. This type of informal learning typically takes place outside the classroom. It is conveyed by museums, science centers, and other institutions involved in the organization of several different events aimed at the teaching of science to a heterogeneous audience in a pleasurable way. Apparently, in science centers, chemistry is still poorly represented when compared to other sciences. The very rare chemistry-focused exhibits may be explained in part due to safety concerns, to high supply costs, and to the need for someone with the right knowledge and skills that may be able to conduct demonstrations. A further difficulty relates to the design of the exhibit, since it is very difficult to display chemical representations connecting the macroscopic and submicroscopic domains. As it is noted by Christian and Yezierski, there still is a great deal to be explored and understood in these free-choice learning environments.

### SCIENCE IN ELEMENTARY EDUCATION

Several authors have been continuously stressing the need to prepare young people for a future that will require good levels of scientific and technological literacy. Thus, each individual should own scientific and technological knowledge that might enable the comprehension of the important phenomena of the world and the participation in democratic decision-making, from a shared responsibility perspective. Within this framework, we advocate that elementary school should always convey the comprehension of the subjects, of the process, and of the nature of science and, at the same time, should develop a scientific attitude when approaching problems. So it seems uncontroversial that science education in early school years offers a key contribution to the promotion of scientific literacy, i.e., it provides “all children with the significant knowledge and understanding of the world around them to enable them to become informed citizens, able to operate effectively and make decisions about science related issues that affect all our lives.”

Teaching young children has always been a difficult and challenging task. Hands-on activities are considered a successful way to teach young children because they allow the children to act in several different ways while they get a direct and visible reaction to their actions. Though attractive to students, without the proper framework hands-on activities may fail to hold students’ engagement in chemistry in the long run. By providing students with an adequate narrative substratum, storytelling may help them to perceive and elaborate meaningful links between the hands-on activities and everyday phenomena. Apparently, this combination of hands-on activities and storytelling calls upon both logico-mathematical and narrative modes of thinking and turns the learning experience more holistic and more effective, as can be proved by empirical evidence.

### THE STORYTELLING APPROACH

Storytelling has always been a powerful way to teach. It was this way that families, tribes, and nations ensured that their stories, lineages, and traditions were preserved. In the present, effective storytelling still remains an important teaching and theory building tool, despite the profusion of written texts and the new information and communication technologies that make everything more accessible than ever. Storytelling paints a picture that captures the listener’s attention, interest, and imagination. Strengths of storytelling include the following: (a) in a relatively small number of words, stories carry large quantities of information in a format that makes it easily assimilated by the listeners; (b) a well told story is capable of promoting mental skills that improve memory, and trigger discovery, exploration, and re-imagining processes, providing a framework for subsequent learning; (c) storytelling shares experience and context, accommodating various perspectives and realities. This enables students to participate from their own cultural frame, creating better self-awareness and “bringing cognition, emotion, and action together” to promote reflective learning.

There seems to be a growing consensus that children’s literature (including picture books, fiction, and nonfiction) can be used to teach science and to promote interest and positive attitudes toward learning science in early years. Literature supports children’s interest in learning science because it makes learning more relevant: offering opportunities to make observations, raise questions, and reach conclusions from evidence in an environment that is meaningful.

Sackes et al. discuss the benefits and limitations of using children’s literature in introducing science concepts to young children. According to these authors, researchers have identified several limitations in children’s books, including misconceptions embedded in the texts, inaccurate illustrations, fantasy, and anthropomorphism. Broemmels and Reardon suggested that teachers should discuss fantasy aspects in opposition to science concepts included in these books, in order to clarify the inconsistencies. Although anthropomorphism might lead children to think that animals, or inanimate objects, can talk like humans, several researchers seem to agree that it is not a specific or considerable problem in science learning if students are motivated to ask questions and think about the content. On the other hand, misconceptions embedded in texts and inaccurate illustrations seem to present the most serious obstacles to learning scientific concepts. Pringle and Lamme also argued that the science background of the author could be an important factor in writing and illustrating books about science.

Using children’s literature in elementary education to teach science concepts to young students can be an effective pedagogical approach, if the stories are carefully chosen, and this approach has become a common practice. As an example we can mention Patricia B. McKean’s books, which meld pictures with chemistry activities. We can also mention the activities integrating the popular Harry Potter books with hands-on experiments suggested by Wally et al. that generate excitement in elementary school students.

### THE DRAWING APPROACH

Children’s drawings have long been studied from different theoretical perspectives and scientific areas. Furthermore,
drawing has been used to promote scientific literacy (ref 46, p 24):

If teachers understand how to read visual compositions in an informed way, they can see how these function as part of the child’s construction process. This knowledge and an understanding of scientific literacy enable the teacher to offer new possibilities and new tools, broadening the context that the child brings to the science experience.

In fact, there are countless pedagogical advantages in a multimodal approach that includes drawing; it contributes to enriching the available resources; it gives a comprehensive perception of work; and it highlights the importance of the teacher as a role model.

Rather than dwelling on the existing criticism to a structuralist approach to the evolution of children’s drawing (e.g., see Fawson45 for a review), we wish to emphasize, with Luquet,46 the importance of visual realism, regardless of the possibilities of working from a visual grammar. According to this author, although visual realism might be desirable for adults, intellectual realism seems to be more suitable for children. One of the consequences of learning how to draw is a well-developed power of observation. When you ask a child to draw a picture, you might attract the child’s attention to new issues whose existence was ignored before, and trigger the development of internal models. When a child draws an object, rather than ON visual realism, the child draws based on intellect realism, representing every detail of the reproduced object, each in its specific way, to a certain extent, performing a spontaneous dissection of the object.

The drawing works, at the same time, as a means of building knowledge and a means of communicating knowledge. To that extent, the drawing has its own grammar which may lead to reflection about the concept under consideration: “This centers the science experience on neither the science activity nor the drawing activity, but on the science concept”.46

■ "STORYTELLING WITH CHEMISTRY": WRITING STORIES FOR YOUNG CHILDREN

These are some of the questions that young children often ask their parents: “Why does water freeze?”, “Why does bread go moldy?”, “Why do party balloons escape to the sky?” When we answer their questions, science is used to both inform and entertain. When we encourage children to ask questions, make predictions, offer explanations, and explore in a safe environment, we lend them the kind of support that they need to become successful science students and scientific thinkers.49

Group book reading and storytelling is a possible way to reach this goal with younger children. That is how we have decided to write a storybook, aimed primarily at elementary school students. The book was written with some important steps for story shaping50 in mind. It includes seven stories about chemistry, told in a simple and introductory way. The word “chemistry” (“química”) is used in the title—_Histórias com Química_ (Storytelling with chemistry)51—and is also used throughout the text, combining real-world and fictional scenarios, and trying to emphasize the importance and application of this science. The stories include three characters: Tomás, the narrator, and the twins, Lina and Pepo, who are the main characters of the adventures. We chose one of the seven stories to use in the investigation: “Tudo as escuras” (“All in the dark”). This is the story overview: In the context of a birthday party, a balloon escapes through the window and flies up high in the sky. The twins try to catch the balloon and end up getting lost in the dark forest. They meet an owl, who helps them understand why the helium balloon has escaped. The owl also explains the chemistry behind the yellow bulbs in the street lighting, which went out and left the village in the dark. We can find two chemical ideas in this story: (i) the introduction to the concept of density and (ii) a reference to the applications of chemical elements helium and sodium. For a better understanding of the stories and illustrations, Figure 1 shows an extract of the story “Tudo as escuras” (“All in the dark”).

A group of young students was involved in a storytelling experience, followed by hands-on activities, which took place in an informal learning environment. We tried to identify possible uses of drawing, as a strategy for the appropriation of chemistry by the young students. An overview of an activity is given below.

■ OUR ENGAGING OUTREACH PROGRAM IN “ROMULO” SCIENCE CENTER

Setting and Participants

This study took place at the science center “ROMULO—Centro Ciência Viva da Universidade de Coimbra” (CCVRC), in Coimbra, Portugal. The convenience sampling consisted of 29 young students from an elementary school near Coimbra, aged 8 to 10 years old. Students’ curriculum includes a science class, Estudo do Meio, covering introductory Physical and Social Environmental studies, focusing on the living beings, the climate, the relief, the planets, and the stars, among others, but without any chemistry content. Though students never learned chemistry formally, a small number of them revealed that they had engaged in hands-on activities before, during extracurricular activities in their schools. It can be said that the sample’s previous knowledge or experience in chemistry was residual.

Materials

Drawing and painting activities can provide us indicators about the child’s emotions, thoughts, perceptions, concepts, reactions, preferences, and skills. In this study, drawing activities, appropriate to the age level, have been used to gather data.52

Figure 1. Extract from the story “All in the dark” (the illustrations were originally created for the book51). Reprinted with permission from ref 51. Copyright 2012 Carla Morais, Pedro Teixeira, and QuidNovi.
Procedure

The students were accompanied by two monitors and by their teachers, who did not directly intervene in the activities.

A festive atmosphere was created. Students wore hats and were given whistles and party balloons. Volunteer students were invited to read the story “Tudo as escuras” (“All in the dark”) (see Figure 1). In the end, students were asked questions about their understanding of the story, with the purpose of emphasizing the chemical elements mentioned and the concepts covered. The questions asked were: “What is the name of the story?”, “Who are the characters in the story?”, “What happened to the balloon?”, “What did the Owl teach the twins?”, “Which chemical elements were mentioned in the story?”, “Where can these chemical elements be found?”, and “How did the story end?”.

After the story was told and interpreted, students were then taken to the space where the hands-on activities would be held.

As the story addressed the concept of density, a specific hands-on activity about this concept was designed and was given the title “Lava Lamp”. For this activity, liquid materials, such as colored water and oil, were mixed inside a glass jar. To the two immiscible liquids were added effervescent tablets. The release of carbon dioxide “dragged” some of the colored water to the surface of the oil layer. Being denser than the oil, the colored water flowed down back to the bottom of the jar. Students took part in the activity and were encouraged to observe and interpret the results.

The chemical element sodium was introduced in the story followed by two hands-on activities involving this chemical element. Thus, during the activity “Filling a balloon”, baking soda was introduced into a balloon, which was inserted around the neck of a glass bottle that had previously been filled with some vinegar. The balloon was then tilted causing the baking soda to fall into the vinegar. The chemical reaction between the baking soda and the vinegar’s acetic acid produced carbon dioxide, which filled the balloon. Colored “Silly Putty” polymers were also made. The students prepared a sodium borate solution and added glue and food coloring, each student choosing a favorite color. The chemical reaction involves polymerization. Colored “Silly Putty” are synthetic polymers resulting from the chemical reaction between poly(vinyl alcohol) (from the glue) and sodium borate. Students were told that they were allowed to take the “Silly Putty” home with them. During the whole process—the previous instructions, the actual experiment, and the discussion of results—the close relation of the hands-on component with the story previously told was continuously stressed. A fourth activity was carried out—“Volcano”—which had no direct relation with the storytelling activity. The volcano cone was shaped using sand around a small cylindrical jar, into which some effervescent tablets were mixed with red dyed water and dishwashing detergent, whose reaction simulated the molten lava flow.

Once all hands-on activities were completed, students were asked questions about their understanding of what they had experienced. An equal number of questions were asked about each activity. The questions asked were as follows: “Describe, in your own words, the beginning of the experiment”, “What happened during the experiment?”, “How did the experiment end?”, “Which chemical element mentioned in the story is present in the experiment?”, or “What did we learn with the story that can help us understand this experiment?” In the end a summary was made with the students, and blank sheets of paper and colored pens and pencils were handed out. Then, students were asked to draw a picture in which they would represent what they felt was most important about the informal learning experience. As some of the students could not complete the drawings at the CCVRC their teachers volunteered to let them continue the drawings in the classroom and promised to send them to us later (n = 17).

Data Analysis Procedure

In the analysis of the research data, the content analysis technique has been employed. Content analysis is a qualitative research technique, which is not limited to the analysis of the texts but also addresses the analysis of the drawings, including science-related topics. During the exploratory analysis of the drawings, two axes of categories emerged: one that comprehended the experiment the drawings referred to, and another that comprehended the foci of the drawings.

<table>
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<tr>
<th>Table 1. Themes and Foci of the Drawings</th>
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<td>Drawings’ Theme</td>
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<td>-----------------------------------------</td>
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<tr>
<td>Lava lamp</td>
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<td>Filling a balloon</td>
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<td>“Silly Putty”</td>
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<tr>
<td>Volcano</td>
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<tr>
<td>Multiple experiments</td>
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<td>Indefinite or unidentified</td>
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(a) the experiments; (b) the set of experiments; or (c) indefinite or unidentified experiments. The drawings were also analyzed according to the object, i.e., (a) if the drawings were focusing on the product of the experiments (e.g., a picture of the balloon filled with carbon dioxide produced by the chemical reaction, or a picture of a hand holding and shaping the “Silly Putty”); (b) if the drawings were focusing on the chemical process underlying the experiments (e.g., a picture of colored water and oil being mixed and effervescent tablets being added
to the mixture, or a picture of sodium borate being mixed with the glue and the food coloring and originating the polymer); (c) if the main reason for the drawing was the student himself (e.g., the student ignores the story or the experiment and draws a picture of himself or herself (the actor) engaged actively in the process); (d) if the story told was portrayed in the drawings.

The relatively open nature of the activity led to drawings with several different foci. As can be seen in Table 1, each experiment was depicted in at least one drawing. The expressiveness of the drawings shows the investment and the interest aroused by the activities, with emphasis on the final product, especially when it became the property of the child ("Silly Putty", 8 drawings; e.g., Figure 2A). We believe that the increased emphasis that the students placed on the hands-on activity “Silly Putty” is due to its relationship with the story previously read, due to the fact that both include the chemical element sodium as a reagent: some students drew the reagents used in the experiment (namely, the borax solution) along with the polymer. But the enthusiasm and preference shown by the students may also be due to the fact that the students were able to mold the polymer with their own hands and were allowed to take it home with them.

Chemical processes were even better portrayed in the “Lava lamp” experiment, where the two phases were correctly represented according to the density, and effervescent tablets were pictured on the bottom of the container causing the release of gas carbon dioxide (Figure 2B1,B2).

The “Filling the balloon” experiment was less frequently chosen by the students, although it also had a close relationship with the story told, through the presence of the balloon and the chemical element sodium, as a constituent of sodium bicarbonate (Figure 2C).

Some of the students’ drawings do not allow us to know which experiment was more meaningful to them as they represent the whole experience they lived in CCVRC: from the storytelling moments to the hands-on activities (Figure 3A).

The storytelling moment is represented in two drawings (Figure 3A and Figure 3B). In Figure 3B we can observe a juxtaposition of elements of the activity “Volcano” and the storytelling. Since the story did not include any reference to volcanoes, we cannot tell if this picture is a simple distorted recollection or if it is a personal synthesis illustrating that chemistry underlies all transformation processes. In fact, the purpose of this work was not to evaluate the memorization of chemical concepts but rather the understanding that chemistry is a transversal science to all transformation processes.

Some students chose to represent all the hands-on activities. In this case, the process resembles a graphic narrative of successive type without repetition (cf. Luquet48). As it is shown in Figure 3A and 3C all the experiments were represented in the final stage and in a single image.

A final evidence that reveals the students’ involvement is related to the presence of several images of the children themselves, particularly in the actor-centered category in which the authors emphasize the experience of a protagonist (themselves) rather than the experience itself (which as in Figure 3D is unintelligible).

We hold, therefore, that drawing, in the context of informal education, when proposed as a relatively open activity, is a relevant indicator not only of the interest aroused by the scientific initiation activities but also of the degree and quality of the appropriation of concepts explored in the activities. Indeed, the possibilities of plastic expression commonly accessible to children seem able to provide indicators of personal ownership and understanding of introductory activities to chemical phenomena. Therefore, the drawings are...
not mere illustrations; accessories of the verbal discourse, i.e., the drawings, may add information value for themselves.

Moreover, while some drawings are very effective capturing a moment in the process, others are particularly eloquent in a narrative way.

CONCLUSIONS, LIMITATIONS, AND FUTURE STUDIES

In this article we described an activity where a moment of storytelling and hands-on activities were combined. We sought to map the possibilities of drawing as an indicator, separated from verbal discourse, in informal educational activities as promoters of scientific literacy.

The hands-on activities, prepared by the prior storytelling, may engage students through listening, reading, imagining, understanding, making, and explaining, and thus can generate interest in science and scientific research.

The drawings seem to show that the hands-on activity that had more impact on the students was the “Silly Putty” experiment. This was the only product of an experiment that could be saved, thus acquiring an ownership potential of simultaneous symbolic and material nature, becoming a product-symbol. Nevertheless, a better understanding of the reasons behind this impact could result from the students’ response to the following question: “Why was this important to you?”. The activity with the “lava lamp”, which addressed the concept of density, and had a more direct relationship with the story told, was also depicted in the drawings of the students. Despite the fact that our sample is too small to allow generalizations, it could be said, however, that our study produced indicators which seem consistent with the idea conveyed by several authors, that the use of appropriate and carefully chosen stories, combined with hands-on activities, may be an effective pedagogical approach to promote the attraction of young students to science and teach some of its concepts.

The impact of the activities on the students can be assessed through oral discussions or through the drawings that they produced at the end of all activities. Through the drawings, the students have proved themselves able to identify the product, the process, the parties involved, and the relationship of each experiment with the story told. Thus, students have shown themselves to be aware of technical and scientific matters, becoming immersed in the human and social context of the process of building science.

As noted by Luraschi, Rezzonico, and Pellegrini, it is crucial that several activities be promoted in science centers, where children can meet science not a crazy, but a normal and relevant science—and where children can see that chemistry is synonymous not only with bad things but also with benefits and discoveries. While paying attention to the negative consequences that arise from the development of chemistry, it is important that, from early on, students be given an antidote to “chemophobia” and be aware of the importance of this science to our quality of life.

In the future, we intend to go on disseminating these activities, while developing a Web site, with Portuguese, English, and Spanish versions, to promote and disseminate these experiences also in Latin America.

The results that we have attained raise new questions and suggest new research topics. So, we highlight the following topics for future research:

- To determine the scientific and pedagogical benefits of using significant figures in the child’s world, such as teachers and parents, to structure the discourse on chemistry topics.
- To ensure that this project is carried out in a systematic way, by including follow-up moments, such as discussions on the story told and on the experiences, and comparing the responses at oral, written, and plastic levels, including an effective evaluation of the learning gains.
- To investigate if there will be any advantage in using these stories to teach subjects in formal learning environments, comparing this approach with traditional teaching approaches.
- To ascertain if the teachers and the students can collaborate in the writing of new stories with chemistry.
- To find out the image and opinion that young students have about chemistry before and after participating in this kind of informal learning experience. For that purpose a longitudinal study must be carried out that will provide the students with several different educational experiences.

Given the disappearance of boundaries between the various areas of children/students’ life, it is crucial to involve their teachers so that increasingly robust bridges can be built and relationships between formal and informal chemistry teaching be narrowed at all educational levels. It is also crucial to involve the parents in the informal learning activities, inviting them to actively participate in the storytelling and to perform the learning activities, along with the children.

All this has the goal of promoting a more and more present and active scientific literacy.

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Notes

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