The Chemistry of Cat Litter: Activities for High School Students To Evaluate a Commercial Product’s Properties and Claims Using the Tools of Chemistry

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**Supporting Information

ABSTRACT: Educating future scientists and citizens is more effective if students are guided to correctly apply what they learned in school to their daily lives. This experience-based work is focused on the study of a well-known commercial product: cat litter. This material offers different starting points for a critical examination. Questions related to physical properties at the origin of the litter’s efficacy, to information on chemical composition provided in the packaging, and to environmental features and possible noxiousness of cat litter were asked to be investigated by secondary school 14−15 year old students, through laboratory experiments based on problem solving approach, analysis of tag claims of different cat litter brands and cooperative learning activities. This multidisciplinary approach gives the chance to learn effectively chemistry core concepts and to avoid the typical students’ lack of attention.

KEYWORDS: High School/Introductory Chemistry, Laboratory Instruction, Inquiry-Based/Discovery Learning, Problem Solving/Decision Making, Consumer Chemistry

■ INTRODUCTION

Chemistry teaching does not usually focus on the interplay of science, technology, and society, despite that this kind of approach has been very effective in education research carried out in Italy and abroad. The Italian school curriculum includes these topics, but teaching practice in them is not much developed.

The perception of chemistry relevance in everyday applications enables students to go beyond the surface features of phenomena, and learning of chemistry key concepts can be more effective. An approach centered on real world problems can help to counteract the typical lack of attention characterizing 14−15 year old students. The present study focuses on a teaching sequence of didactic activities centered on questions related to cat litter, and learning outcomes of chemistry core concepts are compared with those of students not involved in the project. The teaching sequence was carried out during the 2012−2013 and 2013−2014 school years, with four classes of 14−15 year old students of a technical high school in Italy, for a total of 74 students.

■ CHEMISTRY BACKGROUND: CAT LITTER FORMULATIONS

Cat litter is a well-known product. It is a cheap material, existing in a wide variety of types, largely available and safe in order to perform simple experimental tests. Cat litter’s most common material is clay, although silica-based “crystal” variants and recycled paper “pellets” are also used. The biochemist Thomas Nelson observed that a certain type of clay clumped up in the presence of moisture, so he developed the clumping litter in 1984. Clumping/not clumping clay cat litters are natural products. Nevertheless, silica particles found in clay cat litters are known to be carcinogenic. Moreover, environmental impact in using commercial cat litter has become a matter of concern: clay litter is commonly produced in an environmentally degrading process using strip mining. Some pet owners prefer the environmentally friendly biodegradable litters, made from various plant resources. This type of litter does not contain carcinogenic silica dust. Silica gel litter, often referred to as “crystal litter”, is a porous granular form of silicon dioxide dotted with tiny pores, allowing crystals to absorb cat urine and allowing the water to evaporate off.

Many types of cat litters are for sale, so quite often people are undecided about the right choice. Most people usually decide on price criteria; others take into consideration the need of reducing smell or are concerned about disposal of clay with absorbed urine. Rarely, people buy cat litters exclusively on the basis of environmental criteria.

■ LESSON PLAN

The teaching sequence starts with four questions asked to the students:

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1. How can the physical properties at the origin of the litter’s efficacy be evaluated? How much does the method of extracting or synthesizing cat litter influence cost?
2. What information does the packaging provide about composition? Can we carry out chemical tests?
3. How can the product’s sustainability be proved? Can we plan experiments to evaluate the product’s rate of decomposition?
4. Why do some scientific articles deal with possible cat litter noxiousness?

At the beginning, the teacher leads students in analyzing six product samples (Figure 1). Then, the teacher plans research and laboratory activities in order to answer previous questions. The didactic sequence is structured in four sections (sections 1–4), each corresponding to one of the questions above; each section is organized into three phases:

- **Phase I**: Critical approach to the proposed issue. The teacher introduces the issue and assigns related homework.
- **Phase II**: Laboratory experiments/analysis of documents in order to answer the question.
- **Phase III**: Critical analysis of tags’ claims of commercial cat litters; research about some compounds (origin, costs, safety).

**Table 1. Chemistry Content Involved in Sections 1–4 of This Activity**

<table>
<thead>
<tr>
<th>Student Activities</th>
<th>First-Year High School Chemistry Syllabus Contents</th>
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<tbody>
<tr>
<td><strong>Section 1</strong></td>
<td></td>
</tr>
<tr>
<td>Organoleptic characteristics (dry and wet sample) analysis</td>
<td>Differences between homogeneous and heterogeneous materials; insoluble aggregates and heterogeneous mixtures</td>
</tr>
<tr>
<td>Liquid or gas absorption capacity evaluation</td>
<td>Liquid/gas, gas/solid, liquid/gas mixtures; solutions, colloids, coarse dispersions; intensive and extensive properties</td>
</tr>
<tr>
<td>Density measurement</td>
<td>Basic and derived units; errors and uncertainty in experimental data; absolute and relative errors; systematic and random errors; precision and accuracy; rounding off/up experimental data; significant digits in addition, subtraction, multiplication, and division operations</td>
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<tr>
<td><strong>Section 2</strong></td>
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<tr>
<td>Critical analysis of tags’ claims of commercial cat litters</td>
<td>Percentage concentrations in solid mixtures; solid particle dimensions</td>
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<td>Solubility evaluation; solid–liquid extraction; Paper/thin layer chromatography</td>
<td>Separation techniques</td>
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<tr>
<td>Flame test; Borax bead test</td>
<td>Macroscopic metal properties referring to the periodic table; chemical transformations</td>
</tr>
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<td><strong>Section 3</strong></td>
<td></td>
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<tr>
<td>Critical analysis of tags’ claims of commercial cat litters; research about some compounds (origin, costs, safety)</td>
<td>Information about safety of chemicals; differences between natural and synthetic compounds</td>
</tr>
<tr>
<td>Theory on composting process (under different temperature, humidity, or sunlight conditions)</td>
<td>Differences between physical and chemical transformations; chemical transformations</td>
</tr>
<tr>
<td><strong>Section 4</strong></td>
<td></td>
</tr>
<tr>
<td>Research about particulate matter dangers</td>
<td>Suspended solid particles in the atmosphere; chemicals’ safety and health protection issues</td>
</tr>
<tr>
<td>Reading of simplified research papers; discussion/expression of critical points of view</td>
<td></td>
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of the work, carried out by cooperative learning in students’ groups.

- Phase III: Global examination of the accomplished work to develop metacognitive skills. Students try to answer questions related to phase I. This phase is also centered on cooperative learning strategies.

Table 1 describes a synthetic overview of issues involved in each section, with the corresponding chemistry contents and teaching strategies. The learning activities are listed in Table 2.

**Section 1, Question 1: Chemical Properties**

For this section 6 h of class time is required. The students’ worksheets 1–4 in the Supporting Information describe in detail the activities carried out. They are aimed at developing the students’ skills in analyzing different systems of matter and evaluating some physical features, such as the density and the adsorption ability of cat litters.

**Phase I.** Students are asked to observe and describe six samples of cat litters. Each tag is analyzed by the students and compared with the others.

**Phase II.** Different samples of cat litters are assigned to students’ groups, and they communicate to each other their remarks and final results. After the organoleptic feature evaluation of dry and wet samples, students measure the density through the water displacement method, evaluating some physical features; such as the density and the adsorption ability of cat litters.

**Phase III.** Students are guided in formulating some hypotheses, helped by some very simple experimental tests (as flame test[11] and Borax bead test[12]). The teacher suggests that students should send an e-mail to manufacturers of silica gel litters containing blue or pink grains, in order to get more details about the nature of the dye and the origin of claimed bacteriostatic activity.

**Phase Ia.** The flame and Borax bead tests give negative results.

**Phase IIIa.** Students’ groups are asked to elaborate some conclusions about the presence of metals in the analyzed samples.

**Phase Ib.** Only two companies replied by e-mail to students’ inquiries. The company producing silica gel cat litter with pink grains answered: “the dye is allowed by the European Union”, without specifying its chemical nature. According to claims of the company producing silica gel cat litter with blue grains, the coloring agent is based on anthocyanins and its function is just aesthetics, denying the bacteriostatic function reported on the tag. A document about anthocyanins is given to students, and they are asked to propose a suitable separation method for anthocyanins’ detection, among techniques already studied in previous lessons.

**Phase IIb.** Once solubility test[13] results are obtained, thin layer chromatography and paper chromatography[14] are carried out by using the alcoholic extract from the blue/pink samples. Figure 2 shows the experimental steps aimed at verifying the anthocyanin content in the colored silica gel grains. Only the rate of migration of blue extract was different from that of the other samples; therefore, anthocyanins are not present in the blue extract (Figure 3). Also the laboratory test carried out on the execution of chemical tests to confirm the presence of some cobalt compound. This evidence suggests that the dye is probably embedded in a glass structure. The teacher then suggests that students should send an e-mail to manufacturers of silica gel litters containing blue or pink grains, in order to get more details about the nature of the dye and the origin of claimed bacteriostatic activity.

**Figure 2.** Experimental sequence to verify the anthocyanin presence in the silica gel litters with blue and pink grains.
pink extract (possible color change depending on pH variation) was negative.

**Phase IIIb.** Assuming a correct execution of chemical tests, false information has been provided by cat litter producing company.

**Section 3, Question 3: Product Decomposition**

For this section 4 h of class time is required. The students’ worksheets 19–21 in the Supporting Information describe in detail the activities carried out. For each analyzed cat litter, students are asked to organize a schedule containing information on the chemical composition and its composting procedure.

**Phase I.** Some silica gel litters are described as environmentally friendly products, since they will “turn out into sand” because of their “digestive process in 4–6 months by light and water action”. In order to verify the exactness of this information, the teacher assigns homework based on reading a document about the composting process.

**Phase II.** During this phase each students’ group is asked to plan laboratory experiences under the teacher’s supervision, on the basis of contents learned in the previous phase. At the end, all planned experiences are merged into a single collective experimental proposal.

**Phase III.** Students plan the structure of a hypothetical schedule, exactly specifying the chemical composition of any litter and describing the way of composting in a concise, complete, rigorous, and understandable form.

**Section 4, Question 4: Particulate Matter Research**

For this section 6 h of class time is required. The students’ worksheets 22–24 in the Supporting Information describe in detail the activities carried out. The section is devoted to develop students’ abilities in searching information on a scientific issue and comparing research reports.

**Phase I.** Two simplified research reports about cat litter’s noxiousness, caused by particulate matter emission, are given to students to provide them with some examples of experimental methods used in research laboratories.

**Phase II.** After analyzing each case study, students achieve some learning outcomes such as texts’ comprehension and subject knowledge. In detail, they acquire knowledge about particulate matter characteristics, origin, and possible health dangerous effects. Sentence completion exercises and multiple choice tests are assigned to the students.

**Phase III.** Students list the main differences between the two research reports and choose which appears more reliable. Of course, this part needs a specific support by the teacher.

**FINAL RESULTS**

The outcomes of this teaching sequence are essentially qualitative data because of the limited number of students involved. Nevertheless, they suggest a certain efficacy. Students appreciated the activities proposed, in particular the laboratory work. A student stated, “Chemistry is not so boring as I’ve been thinking for a long time: we can use many daily life products to understand it.” Our teacher raised enthusiasm in us, especially when we discovered that the company very probably lies on dye’s chemical composition.” Another student seemed fully satisfied: “Finally I can manage with relative and absolute errors, or with the procedure to calculate the error related to a quantity (such as density) obtained by the division of two other quantities. It was funny to understand all that stuff by experiments on a cat litter!” Concerning the experimental activities, a student affirmed: “I liked very much the chromatography experiment: although we have not discovered the nature of the dye, we were able to exclude a hypothesis.” A student admitted: “When the teacher asked us to study samples of different cat litters, I started to laugh. I thought it was a not suitable material for school work. But now I know that I can learn a lot from everything: each object hides secrets.” Students were mainly surprised by the falsity and/or incompleteness of publicity information by companies of cat litters: “They stated by e-mail that colored granules have an aesthetic function only. So, why did they write on the package their function is antibacterial? Aren’t they afraid of the consequences?” and “Why did they answer the dye is authorized by the European Union without specifying its chemical composition? Why are silica gel litters produced in China? Answering all these questions need a lot of time in gathering information. I realized that any product we use brings with it very complex issues.”

The final test on some chemistry contents showed that the outcomes of classes working on the project were considerably higher than those of the control group. Language, critical thinking, problem solving, and analysis skill development of the
students involved in the project were also assessed by the evaluation of worksheets filled during the school year.

To answer in a definite and complete way the complex questions posed is of course not possible, especially in a school laboratory. Anyway, the main expected outcome was related to the inquiry students' skill development in order to formulate a more mature vision of chemistry and its relationships with everyday life, global problems, and ethical issues.

### CONCLUSIONS

We have designed a novel didactic activity centered on the study of cat litter, a largely available and safe commercial product existing in a variety of types. Then we have run the didactic sequence with Italian secondary school students of 14–15 years old. They were asked to investigate some questions on this product (physical properties at the origin of the litter's efficacy, information on chemical composition provided in the packaging, product's sustainability and possible noxiousness) by problem solving based laboratory experiments, analysis of various documents, and cooperative learning activities. Within this multidisciplinary approach, in a stimulating educational context, students were strongly encouraged to think and learn actively several core concepts of chemistry.

### ASSOCIATED CONTENT

#### Supporting Information

Students' worksheets including hazards. This material is available via the Internet at http://pubs.acs.org.

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**Notes**

The authors declare no competing financial interest.

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