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Introducing Chemistry of Cleaning through Context-Based Learning in a High-School Chemistry Course

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Abstract The following paper discusses the implementation of context-based learning to introduce the concepts associated to chemistry of cleaning in high-school students. The methodology proposed in Chemie im Kontext was followed and adapted with project-based learning to ensure key concepts were assimilated and related to students' everyday life. In such a way, the focus was drifted to a student-oriented approach in which students used the scientific method to inquire about the way in which cleaning products work from a chemical perspective. A collaborative approach was conducted to deliver a scientific poster that portrayed their work.

Keywords: *ChiK, context-based learning, project-based learning, collaborative approach, scientific method, chemistry of cleaning, inquiry-based learning*

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1. Introduction

It is well-known that several chemistry concepts are harder for students to grasp, especially if they are taught in such a way that concepts are disconnected from daily life [1]. For the past years, several attempts have been made to improve the way in which science is taught [2]. One approach in Chemistry has been to relate scientific concepts to daily life so that students can see the usefulness from a social, professional, and personal perspective [3]. The emphasis is given then, to understand the relationships between science, day-to-day and social aspects to enable students to take well-informed decisions [4]. Garritz and Talanquer [5] established the need for scientific education that relates scientific knowledge with its application, fostering science through experiments by acknowledging the importance of students´ experiences and their conceptions in understanding phenomena. As such, an integrated insight of science can be portrayed.

Different attempts to improve chemistry education have been documented with the use of inquiry, problem solving, learning progressions and competency - based learning. However, the main obstacle for these approaches is the rigid and vast curriculum that promotes traditional teaching methods [6].

Consequently, the need of a methodology that considers both the chemical concepts from the curriculum and the students' interests is evident [7,8]. Through this analysis, the implementation of Chemie im Kontext (ChiK) [9,10] in the Mexican high-school context provides a set-point to improving the current situation based on the socialization of science, the student-centered approach, and the development of chemistry concepts from a constructivist point of view [11].

The following phases described by Sanchez Díaz et.al. [12] are crucial for introducing content through ChiK:

Phase of contact - The context is presented by connecting it to students' everyday life and living environment, activating previous knowledge, and posing questions on the subject.

Phase of curiosity and planning - A discussion is generated with the questions from the previous phase and research strategies are developed to answer the questions. Students formulate hypotheses and plan the research work.

Phase of elaboration - Methods that foster active learning experiences are used so that students conduct research (individually or in groups), hypotheses are revised, and questions are answered.

Phase of deepening and connection - Contents are related with other contexts in such a way that students' prior knowledge relates to new acquired knowledge and basic concepts are further developed.

By merging ChiK with project-based learning, several misconceptions regarding the use of cleaning agents were addressed in which students had the opportunity to create a cleaning agent to test its efficacy in different materials.

2. Methodology

A total of 45 high-school students, aged between sixteen and seventeen, participated in the project. These students belong to the Multicultural program at PrepaTec, Campus Estado de México and were enrolled in two different groups from the subject "Matter and Sustainability". The project was set as a "core activity" for the subject, aiming to promote the competences of scientific thinking and collaborative work and lasted 15 weeks.

As part of the contact phase, a one-hour brainstorming activity took place (Table 1) in which students made questions in terms of what they wanted to know about chemistry of cleaning [13]. From that session, the following questions (divided into three main sections) came up:

Table 1. Brainstorming about Cleaning Products

What do I know?	What would I like to know?	What do I need to know?
Cleaning agents eliminate microorganisms Cleaning agents have a basic pH They break down fatty molecules They contain alkaline metals They are made up of sulphates They contaminate They are good for removing unwanted substances They are toxic They damage your skin They smell strong They are colorful	What are cleaning agents made of? How can I make a cleaning agent? How can I use products correctly? What part of the formula makes a product harmful? What makes dirt come out? Why do some make foam? What makes a neutral soap special? Does smell influence cleaning? Why are cleaning products colorful?	Main physical and chemical properties Procedure to make a cleaning agent Effects they have on the environment Function of each component in a cleaning product Chemical interactions Health effects Functions of a cleaning agent pH

Students were also asked to individually answer a questionnaire (see appendix) regarding previous knowledge on the topic.

During the curiosity and planning phase, students were divided in teams of four to five members according to their preference. They came up with a research question, hypothesis and established the research plan. Questions from the first session were included in the research plan. They were asked to formulate a biodegradable product and to select tests that would prove the effectiveness against a commercial cleaning agent. They had three weeks to develop this phase, and feedback was provided with the aid of Blackboard (educational platform) before moving on to the following phase. After research, relevant concepts were discussed and presented in class as part of the syllabus, including surfactants, chelating agents, builders, enhancers, sanitizers, chemistry of stain removal, types of cleaning agents, factors that affect cleaning and environmental considerations.

In the elaboration phase, students carried out the experiment to promote an active learning experience. This included first the formulation of the cleaning agent and then the development of two different tests to compare effectiveness with the commercial product. It is worth to mention that the effectiveness tests were chosen by the students, aiming at the different physical or chemical properties that they researched during the planning phase. Final product and videos that showed the tests were assessed by the teachers using a set of checklists (see appendix).

In the deepening and connection phase, students presented their projects in class, using a scientific poster. Both individual and teamwork were assessed (see appendix). The products for this phase were the scientific poster, a reflection on the usefulness of the project and the connection to the use of the scientific method and their daily lives and a document containing all phases of the project (Table 2). Competences were assessed individually according to expected outcomes listed as part of the subject's objectives. In the end, a post-test was carried out to compare students' acquisition of the concepts discussed.

Table 2. Organization Timetable for the project

Phase	Activities	Weeks	Class time
Contact	Brainstorming questions (Table 1) Pre-test	2	1 hour
Curiosity and Planning	Teams Research question Hypothesis Formula Concepts	3	1 hour
Elaboration	Efectiveness tests design Experimental phase Videos	5	None
Deepening and connection	Scientific Poster Individual reflection Presentations Post-test	5	3 hours

3. Results

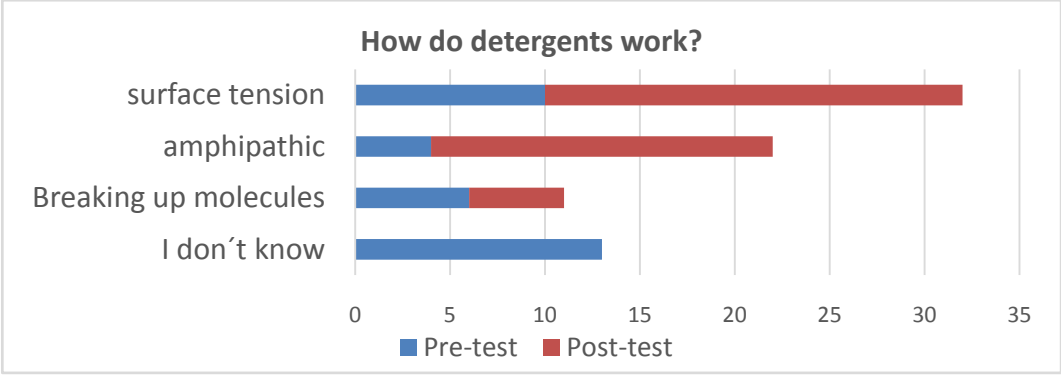

Figure 1. How do detergents work?

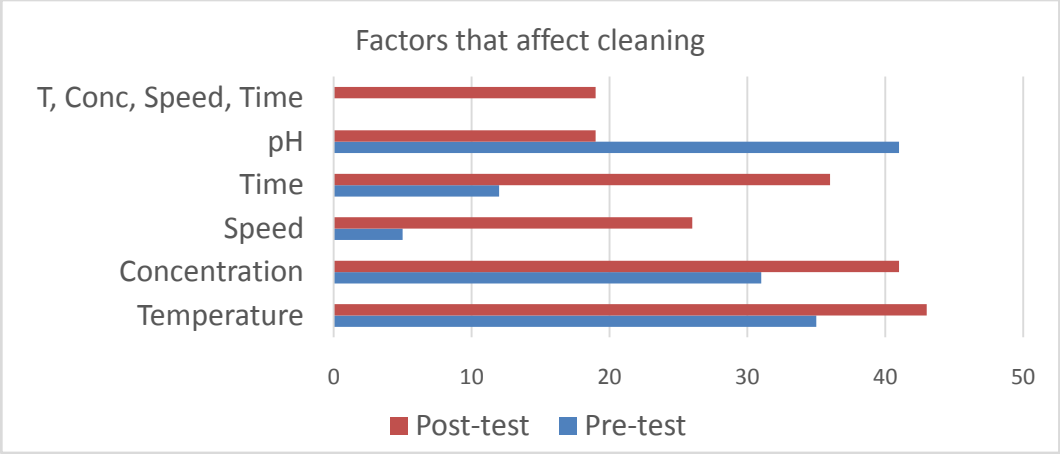

Figure 2. Factors that affect cleaning

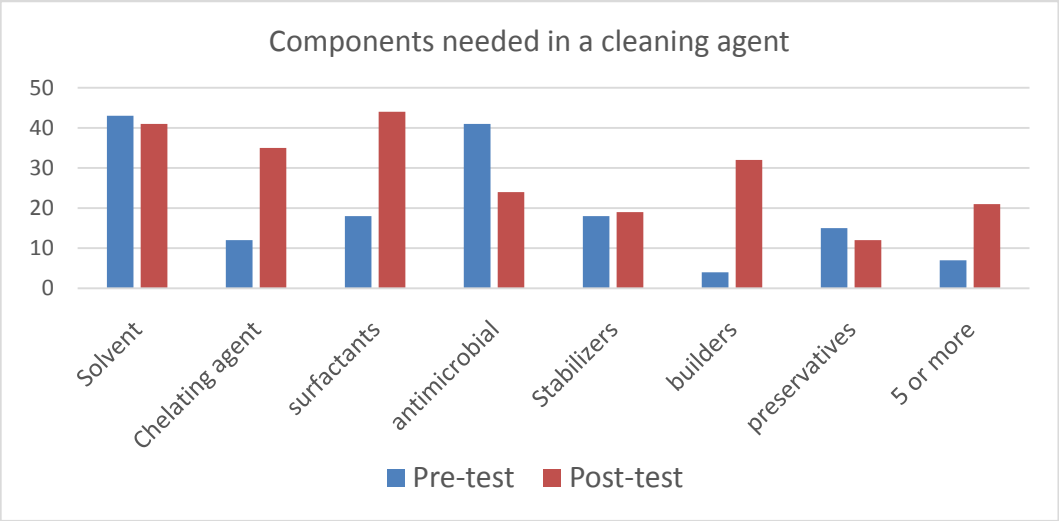

Figure 3. Components needed in a cleaning agent

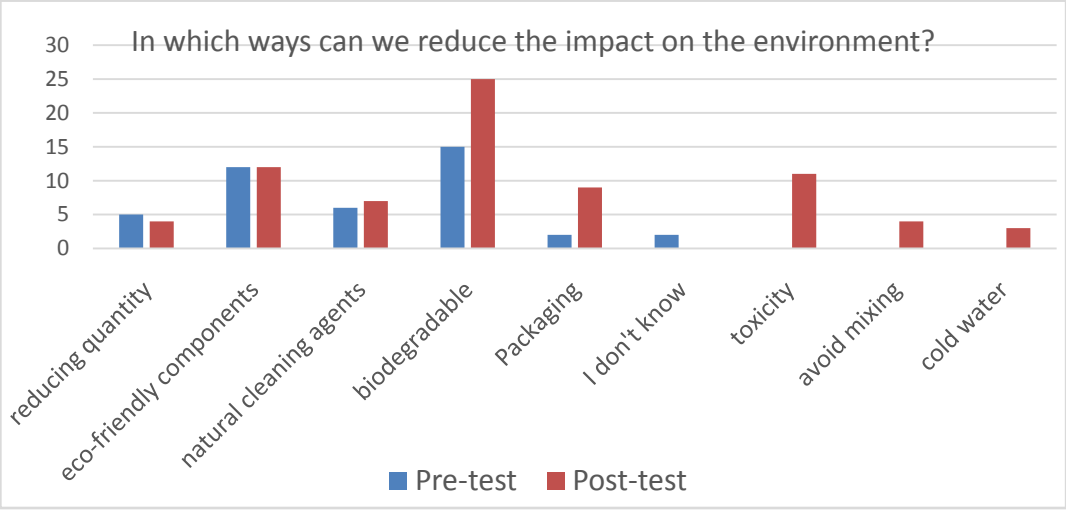

Figure 4. In which ways can we reduce the impact on the environment?

4. Discussion

Graph 1 shows that while developing the project, students were able to understand better how cleaning agents work. The curiosity and planning stage in which most research was done was crucial for students to interiorize concepts such as surface tension and amphipathic molecules which were not clear in the beginning. It is also noticeable that in the beginning, around 33% of students were unaware of how cleaning agents work. By the end of the project, all students had an idea of how it is done.

When the project started, most students were unaware of the fact that there are several factors that can affect

cleaning. Graph 2 shows the assimilation of the theoretical background after the deepening and connection phase, in which almost half of the students interviewed recognized that speed, time, temperature and concentration can affect the cleaning process. When analyzing the components in a cleaning agent, graph 3 shows that most students associated antimicrobial properties with cleaning agents (which in fact it is not always true). After the post test, around 30% of them recognized that many components are needed at the same time to ensure different properties and functions.

Students felt that through the project implementation, they were able to understand better which factors are involved in the cleaning process. Given the context of COVID, students were also able to teach their families how to avoid combining cleaning products that could result in harmful or toxic, so it meant a lot for them to use the concepts seen in class. The project became an eye-opening experience in terms of the impact products have on the environment, so students are now more aware of the effects certain cleaning agents have. This reinforced certain soft skills such as critical thinking and communication, since they are more involved in making decisions on which products to buy and how to choose options that are less harmful to the environment. They also realized that certain environmentally friendly options can be made at home, reducing their carbon footprint, and becoming responsible consumers. Some of the aspects that were mentioned regarding the effect on the environment were the excess of packaging and water contamination, which were not mentioned in the pre-test, as observed in Graph 4. Even though the number of students that considered eco-friendly as an important aspect of cleaning agents did not change, it is important to mention that through the implementation of context-based learning, students were able to use the term more accurately based on the deepening and connection stage discussions. The main goal of contextualizing the topics is for students to become science literates to make reasoned decisions in the future [14].

In relation to the development of soft skills, students considered that time-management was essential to a successful project. Many of them had to deal with loads of emotions such as stress, excitement, concern, and curiosity, which clearly impacted on interpersonal skills by having to negotiate with other team members and organize tasks appropriately [15]. They also felt that one of the worst parts of the task was working through trial and error. This was evident in trying to adjust formulations for their products, when students realized that the cleaning agents were not cleaning effectively. Extensive research was also considered as a problem since students usually lack the skills to evaluate reliable scientific sources. Opposed to that, the making of the product was one of the most valuable stages of the process. The demand for active learning and the soft-skill training, especially in science related areas has been increasing in the last years as a way for students to achieve deep learning. In such way, project-based learning has proven to be an effective strategy [16].

5. Conclusions

Context-based learning in chemistry helps students connect theoretical concepts with daily life aspects that are relevant to them [17]. Through project-based learning, students become active in the learning process promoting the acquisition of soft-skills and scientific competencies. The different phases undergone through ChiK implementation were necessary to guide students through the process, ensuring that the needed concepts were acquired based on the Matter and Sustainability curriculum. Post-tests show that through research and experimentation, students understood and connected better principles on how cleaning agents work, and which factors affect cleaning processes. The purpose should be to provide the students with authentic feedback that would eventually lead to autonomy and self-regulation so that they become active participants of the learning process. To sum up, ChiK methodology can be used in project-based learning as a guideline to structure the design in such a way that students become the center of the learning process and to relate chemistry content to everyday life by promoting meaningful learning.

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Appendix

Annex 1: Chemistry of cleaning questionnaire

The following link leads to a Google form which was used as both pre-test and post-test: https://docs.google.com/forms/d/1zJVF6e2DlJvEwwF0v6Rd2tV6ag8XxV3keJ4Gny5DkTs/prefill

Worth to note, the last three questions were only used as a part of the post-test.

- How did your understanding of cleaning improve by using it in a real-life context to create a product?
- How did you feel when doing the project?
- What would consider as the best and the worst of the whole process?

Annex 2: Students Instructions for each phase

Phase I

Teamwork:

1. Form teams of 4 students maximum.
2. Research the following topics: Explain what a soap is, a detergent and its difference, the historical background, the importance of detergents and soaps, production, how they work, list the most common ingredients found in soaps and detergents, the function of each ingredient and the environmental repercussions of each ingredient, difference between biodegradable and non-biodegradable cleaners.
3. Select a cleaning product (soap or detergent) of any brand you prefer.
4. Formulate a BIODEGRADABLE cleaning agent that replaces the product of your choice. You must include the ingredients and concentration, justify the function of each and its biodegradability.
5. Proof of effectiveness of the proposed cleaning agent. Describe in detail the procedure that will be followed to compare the cleaning power of the formulated detergent with that of the chosen brand. You must do at least two different tests (for example, remove two types of stains, different temperatures, concentration of the detergent to clean a certain surface, etc.) and each one must be done in triplicate. Remember to mention the material and substances you will use, dependent and independent variable of each test and formulate a hypothesis.

Phase II

Teamwork:

1. Prepare 500 mL of the cleaning agent you formulated. Evidence: 2-min video (just share the link in BB).
2. Carry out the effectiveness test of the formulated cleaner comparing the results with those of the agent of the chosen brand. Evidence: 2-min video (just share the link in BB).
3. Report your results in the appropriate way (photos, tables and / or graphs, etc.)
4. Perform the analysis of results, indicating the experimental errors.
5. Write the conclusions and aspects of improvement.
6. Attach the documents obtained in steps 3 to 5 in your first delivery report.

Phase III

Teamwork:

Make a scientific poster with the findings of your research. It is advisable to follow the steps mentioned on the following page:

https://www.elsevier.com/es-es/connect/estudiantes-de-ciencias-de-la-salud/pasaporte-elsevier-como-hacer-un-poster-cientifico-y-no-morir-en- the attempt

Individual work:

Do a reflection using paragraphs that answer the following guiding questions:

What lessons do you take with respect to the application of the scientific method?

How can the scientific method help to develop deeper knowledge in your daily life?

According to the results obtained, what actions could you take to benefit the environment?

What personal challenge(s) did you face and how did you solve it?
Notes:

- You must upload two files to Black Board: one containing the full investigation and the poster elaborated in teams and another with your individual reflection.
- You must respect the delivery dates assigned by your teacher.
- If you do not submit the final individual reflection, you will not be assigned a grade in the core activity.

Table 3. Phase I Checklist

Front page: **School´s name** **Project´s name** **Students´names and ID (ascending)** **Date**	**5%**
Theoretical framework (7 topics)	**25%**
Use paragraphs to describe the following information: • What a soap and a detergent are, explain their difference. • Historical background. • Importance of detergents and soaps. • Production process • How they work. • Most common ingredients found in soaps and detergents, the function of each ingredient and the environmental repercussions of each ingredient. • Difference between biodegradable and non-biodegradable cleaners.	
Citations in the text (theoretical framework)	**5%**
Proposed formula for the biodegradable cleaner.	**30%**
• Chosen product (mention only)	
• Substances	10%
• Concentration of each substance.	10%
• Justification of the choice of each ingredient (function and biodegradability).	10%
Tests of effectiveness of the proposed cleaner (Experimental design)	**30%**
• Two different tests. Specify what you will measure in each.	10%
• Identification of variables (independent and independent).	5%
• Hypothesis.	5%
• Detailed description in paragraphs or flowchart of each test (quantities, experimental conditions, materials and equipment).	10%
References	**5%**
At least 3 references (APA)	

Table 4. Phase II Checklist

Description	Percentage
1. A 2-minute video with the making of the cleaning agent (upload link to BB): - Name of the project is presented - Given name for the designed product - Materials and substances needed to prepare the cleaning agent - Step – by – step method to prepare the cleaning agent - Finished cleaning agent	20%
2. A 2-minute video with efficacy tests (upload link to BB): - Test to be carried out is briefly decribed - Procedure for test is observed - Final results are shown • Remember you should choose two tests to compare your product with a commercial one	30%
3. Results - Results are shown in an appropriate way (photos, charts, graphs) - Graphs and charts contain titles - Foot figures and numbers are included	10%
4. Results analysis - Results are explained through comparison, contrast and theoretical background	15%
4.1 Experimental errors	5%
5. Conclusions. Remember your hypothesis and the objective of the activity: to formulate a biodegradable cleaning product and compare it with one which already exists in the market.	10%
5.1 Improvements. State whether you found something that could be changed (ingredients, presentation of the product, organoleptic properties, etc.).	10%