Perception of Pre-Service Chemistry Teachers about Detergency: From Macroscopic Observations to Symbolic Theoretical Mental models applied to inactivation of SARS-CoV-2

Percepção de professores de química em formação sobre a detergência: das observações macroscópicas aos modelos mentais teóricos simbólicos aplicados à inativação do SARS-CoV-2

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Abstract

This study deals with an experimental proposal and the elaboration of schemes to address the topic of lipids and the effects of detergents in SARS-CoV-2 at the molecular level. The proposal was applied to undergraduate chemistry students (pre-service chemistry teachers). In addition to conceptual learning, the objectives were: 1) to explore or develop procedural, attitudinal, and cognitive skills of future teachers; and 2) to analyze the ability to correlate experimental observations with real phenomena, such as the theoretical interpretation of SARS-CoV-2 inactivation by detergents. Data were obtained from individual reports and schemes constructed by students and analyzed using the Content Analysis method. The main results indicated that the development of experimental activity with pre-service chemistry teachers can encourage them to reason scientifically about simple daily phenomena and favor them to develop scientific literacy. However, the students had difficulty in formulating chemical symbolic hypotheses to explain macroscopically observed phenomena and to explain theoretically everyday situations.

Keywords: Experimental activity; Biochemistry teaching; Lipids and SARS-CoV-2.

Resumo

Este estudo trata de uma proposta experimental e da elaboração de esquemas para abordar o tema lipídios e os efeitos do sabão no SARS-CoV-2 em nível molecular. A proposta foi aplicada a alunos de graduação em química. Além da aprendizagem conceitual, os objetivos foram: 1) Explorar ou desenvolver habilidades procedimentais, atitudinais e cognitivas dos futuros professores; e 2) Analisar a capacidade de correlacionar observações experimentais com fenômenos reais, como a inativação do SARS-CoV-2. Os dados foram obtidos a partir de relatórios e esquemas construídos pelos alunos e analisados pelo método de Análise de Conteúdo. Os principais resultados indicaram que o desenvolvimento de atividade experimental com professores de Química em formação pode incentivá-los a raciocinar cientificamente para explicar fenômenos simples do cotidiano e favorecê-los no desenvolvimento da Alfabetização Científica. No entanto, os alunos tiveram dificuldade em formular hipóteses simbólicas químicas para explicar fenômenos macroscopicamente observados e explicar teoricamente situações cotidianas.

Palavras-chave: Atividade experimental; Ensino de Bioquímica; Lipídios e SARS-CoV-2.
**Title**
Perception of Pre-Service Chemistry Teachers about Detergency: From Macroscopic Observations to Symbolic Theoretical Mental models applied to inactivation of SARS-CoV-2

**Target audience**
Academics of a degree course in Chemistry

**Related disciplines**
Biochemistry

**Educational objectives**
To evaluate the potential transposition of the observed macroscopic phenomena from practical activities with lipids and detergents to abstract theoretical mental models (schemes) explaining the effects of detergents on the SARS-CoV-2.

To explore or develop procedural, attitudinal (decision making during practical activities), and cognitive skills (interpretation and transposition of macroscopic observations to the microscopic and symbolic interpretation of chemical phenomena) in pre-service chemistry teachers;

To analyze the participants' ability to correlate experimental observations with real but sub-microscopic phenomena, such as SARS-CoV-2 inactivation by detergents.

**Justification of use**
This activity is justifiable by the relevance of correlating biology and chemistry contents with real everyday phenomena. Specifically, the inactivation of SARS-CoV-2 by emulsifying agents (detergents or soaps). The use of problematizing experimentation can facilitate the understanding of micro-and macroscopic phenomena and the development of critical skills in students (observation, reasoning, interpretation, questioning, etc.). Furthermore, the proposal will familiarize future teachers with simple experimental activities. The activities can be applied in the school context, using accessible materials present in the school or at students’ homes.

**Worked contents**
Lipids, detergency by Sodium Dodecyl Sulfate (SDS) and SARS-CoV-2 structure.

**Estimated duration**
Application of activities (4 hours). Observation of detergency of animal and vegetable lipids by SDS, construction of reports, and elaboration of schemes (up to 1 week)

**Materials used**
Animal and vegetable lipids and commercial detergent. Assorted containers (plastic or glass cups, plastic egg holders, transparent pots, plastic syringes...)

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1 Introduction

Citizenship education is an emerging demand in today's society [1,2]. In science education, citizenship training should prepare students for an active, informed, and critical participation in society [3,4]. In fact, at least from a rhetorical point of view, someone who is scientifically literate should understand the nature of Science and be able to apply it to solve or decide about real everyday demands [1,3,5,6].

Of particular importance, methodological approaches to teaching can promote the development of more critical and participatory individuals, at least with regard to the basic content of science. Constructivist methodologies that have the student as the center of the educational process [7,8], where the learner is actively involved in the learning [9], should inherently lead to better citizenship training from a social-scientific point of view. However, the contribution of science education to citizenship education is still quite fragile [3] and, in the real world, science educators are dominated and guided by academic contents.

There is a consensus in chemistry and biochemistry that practical activities should be a source of opportunities for students to engage in their own learning [1,10–15]. However, in the context of teaching experimental biochemistry, the “follow the recipe” methodology predominates [16–19]. Consequently, the active participation of the learner is not encouraged and the methodology cannot be considered effective for teaching Science [20–23].

An alternative to overcome this problem would be the development of experiments based on problem solving or inquiry based learning activities [24–26]. The approach drives the resolution of problems of some relevance to the student [27,28]. Ideally, the proposed problems should favor the construction of knowledge and improve important scientific skills, for example, observation, interpretation, argumentation and discussion [17,29].

In remote learning conditions imposed by the COVID-19 pandemic, practical experimental activities in biology, chemistry and biochemistry needed to be remodeled [15,30–33]. Given the importance of such practices for the teaching of Science [1,20,34] and for developing scientific literacy in students [35], it is relevant that experimental activities be part of the students' routine, even if occurring in alternative spaces.

Specifically, experimentation can be a great ally for teaching biochemistry, facilitating the understanding of phenomena at the macro, micro and submicroscopic levels [36]. Furthermore, pre-service teachers can have a better performance in their future teaching practice, if they learn alternative methodologies applicable in the elementary school sce-
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nario [37,38]. Indeed, the experiences lived during the formation process influence the way pre-service teacher will teach science at school [39].

Here we describe practical activities carried out with pre-service teachers from a course of chemistry about lipids found in their kitchens and the action of detergents and soaps on SARS-CoV-2. Here we have adapted problematized experimental activities about detergency of lipids typically performed in laboratories at the university [40] to the on-line classes and experimental activities carried out at the students’ kitchens. We sought to assess the potential transposition of the observed macroscopic phenomena from the practical activities with lipids to abstract theoretical schemes explaining the action of detergents on the SARS-CoV-2. In short, the specific objectives were: 1) to explore or develop procedural, attitudinal (decision making during practical activities) and cognitive skills (interpretation and transposition of macroscopic to microscopic phenomena) of future chemistry teachers; and 2) to analyze the participants’ ability to correlate experimental observations with real phenomena, such as the SARS-CoV-2 inactivation by detergents.

2 Methodology

2.1 Activity development

The activities of this study were applied via Google Meet to nine academics (20 to 30 years old, 1 male and 8 female) of the undergraduate Chemistry Licentiate course at the Federal University of Santa Maria/RS, during the course of Experimental Biochemistry. The experimental biochemistry course aims to train pre-service teachers with simple methodologies easy to be applied in the basic school scenarios. The general experimental activities studied during the semester are grounded in the “macroscopic” observation and interpretation of relatively simple chemical phenomena (without a fixed "follow the recipe" type protocol approach) [40]. Here specifically we problematized the observation on how different lipids interacted with commercial detergents.

The activities about detergency were carried along one week, being initiated in the weekly class period of 4 hours, where the students and the instructors always interacted via Google Meet to coordinate and discuss the activities performed at the students kitchen. Specifically for addressing the subjects of lipids and detergency, the 4 hours period of synchronous activities were used to propose the steps of the experimental activities and to perform the initial observations about the interaction of lipids with commercial detergents (more details will be given below), and to give a few theoretical explanations about the bio-
The chemical constitution of the SARS-CoV-2. The importance of macroscopically observing the interaction of detergents with different types of lipids (previously selected by the students) was stressed.

Furthermore, the specific question about the interaction of detergents with the SARS-CoV-2 was also indicated and the necessity of an individual proposition of an illustrative model to explain on how the detergents or soaps could interact with the structure of the SARS-CoV-2 was briefly presented. The students were also asked to observe and collect daily information about the interaction of detergents with the lipids for one week. It was emphasized that student could do more than one observation per day, but that the minimum was one data collection (including photos with the mobile). The Google Classroom platform was used to post materials, activities and additional explanatory information.

The activities analyzed here focused first on the macroscopic (and easily observable) effects of commercial detergents (in which Sodium Dodecyl Sulfate (SDS) is the main active component) on the lipids found in foods. Specifically, the students were advised to observe and record any observable change in the visual properties of the lipids and detergent after they are put in contact. The macroscopical aspects of the mixture was recorded at least once a day by students for one week. The most frequent recorded aspects were related to the formation of phases, immiscibility, emulsification, change in color, etc. At this point, the instructors gave no cue to the students, only asked “observe and take note of any thing you can perceive”. It was emphasized, however, that the observations made should be used to explain the phenomena biochemically (at the microscopic level).

At the final days of observation (day 6 to 7), students were asked to mix any two phases existing between the detergents and the lipids.

As commented above, during the 4 hours synchronous activities, the students were instigated to theoretically propose how soaps and detergents could inactivate the SARS-CoV-2, which is a coronavirus with lipid bilayer in its external structure [41,42]. Since the activities described here used materials present in the kitchen, they could be easily applied later by teachers in the disciplines of biology or chemistry at the elementary or high school. According to Valls-Bautista, Solé-Llussà and Casanoves [43], the teachers in the basic education have difficulty to work with dynamic methodologies in their classes. Therefore, the introduction of this type of activities during the pre-service period of formation can facilitate the applicability of similar practices in the school context.

To summarize, the proposal was developed in four moments:

First moment (about 15 min-one week before the activities): One week before the synchronous activities described above, students were asked to separate in their homes
two or more fats or oils from animals or vegetables sources to be used in the next week experiments. However, no information was given to them about the on-coming activities. Usually, during the semesters, the final period (usually 10-20 min) of the preceding synchronous meeting of 4 hours was used to ask students to provide during the week the materials required to performed the on-coming activities in the next week.

**Second moment** (about 30min at the begging of the 4 hours interactive (synchronous) activities): The students performed experiments with commercial detergents found in their kitchens and the previously chosen fats (from animals) and vegetable oils. A simple explanatory guide was made available to the participants (the guide indicated “spoon” as the unit of measurement but students were taught that they could use different quantities or units of measurement. It was emphasized that the units or quantities should be enough to standardize measurements of the components of the reactions and to enable easy macroscopic observations of the phenomena about the interaction of lipids with commercial detergents) (Figure 1).

![Lipids Experiment](image)

**Figure 1.** Suggestion of reactions between lipids from animal or vegetable sources with commercial detergents to be carried out by student at their homes. It was emphasized that students could use other “standardized units of volume”, but they were asked to be aware of the “precision” of the selected unit and also to avoid the use of big volumes to be frugal and avoid the release unnecessary quantities of detergents and lipids in the environment.

During this initial period (about half-an hour), some instructions were also given verbally to the participants. Students were also asked to take notes, draw, film or photograph the experiments to compose the report of the activities.

**Third moment** (about 2 to 3 hours): From a small text with illustrations (supplementary material 1 - article page in the journal), participants could get information about the structure of the SARS-CoV-2 (genetic material, proteins and the virus membrane, etc.), emphasizing the presence of phospholipids and protein in the membrane. A small formal
presentation of the slides was made by us to the students (about 15 minutes), where it was emphasized the components of the SARS-CoV-2. During these 2 to 3 hours interval, we have asked the students to do at least 4 observations on the reaction mixtures containing the different lipids and the increasing quantities of detergent (Figure 1). Clearly, we have stated to them: “What you can see macroscopically in terms of changes in the appearance of the mixture? Take written notes, pictures with your mobile, or make a drawing, etc. of the changes.

Fourth moment (about 30 min): Students were then asked to formulate hypotheses regarding the interaction of detergents with the different lipids (as observed and recorded individually by each student) and to imagine what detergent could do on the structure of the virus. The building of models or schemes about the effects of detergents in the structure of SARS-CoV-2 was encouraged by instructors. The deadline for completing this activity was up to five days via the discipline's platform.

In relation to the structure of the SARS-CoV-2 and its composition, the instructor who gave the short presentation about the SARS-CoV-2 (see supplementary material - article page in the journal), explained and gave emphasis about the presence of a membrane-like structure “surrounding” or delimiting the viral particle, containing lipids and proteins. The characteristic of the lipids (phospholipids) were briefly commented (“the head here is polar and the tail apolar”, “they have a stabilizing (tail-to-tail interaction, with the heads in contact with the hydrophilic environments) arrangement forming the bilayer structure of biomembranes”, etc). Specifically, in the slide 4 of the supplementary material (article page in the journal), we emphasized that these phospholipid molecules were derived from the human host biomembranes and important constituents of the viral particle structure. During and after the explanations, the students were invited to search for more information about the structure and properties of the lipids found in the nature.

The experiments using different types of lipids and detergents has been previously validated by us. In fact, in the classes held in the university's laboratories, these activities on detergency have been applied for more than 10 years for the pre-service chemistry teachers. The most important differences between the activities previously carried out at the university and the activities carried out at the students' homes were the use of pipettes to measure volume and Beckers to mix the detergent with different types of lipids in the laboratory and the use of household utensils (or syringes, etc.) in the student's kitchens. In addition, in activities carried out at home, a question trying to link the activities of detergency with the action of commercial detergents in the destabilization of the lipid bilayer of SARS-CoV-2. However, we emphasize that it was only asked: “What do you think that a
detergent does (or can do) in SARS-CoV-2? Build a model to explain this (these) effect (effects).” The inactivation of the virus was verbally mentioned by several students during the activities, but the models were built individually by each one without verbal comments in the group of instructors and students.

From the results obtained here in our present investigation, it was possible to observe that the explanations given by several students indicated that they partially understood the detergency phenomenon and satisfactorily described how a detergent could inactivated the SARS-CoV-2. However, only one student noticed and reported in their model the interaction of the detergent with lipids or with the virus proteins + lipids (Figure 6A). These results show the potential of instigating the explanation of chemical events that are relevant for their lives (and for the society as a whole) with theoretical symbolic chemical models. Therefore, in our future activities we will include and emphasize this type of problematization.

In addition, with proper adaptations to each educational context, we emphasize that this proposal can be applied to Biology and Chemistry undergraduates, elementary and high school students. In fact, the activities described here required simple materials that are found in the students' and teachers’ daily lives. Importantly, chemical and biochemical aspects of reactions occurring every day in our homes can be macroscopically addressed.

The detergency is relevant not only for protection against infections, but also in day-to-day personal cleaning (toothbrushing, body or hand hygiene, etc.) or in the utensils used in the kitchen (plates, glasses, pans, etc.). In fact, in the classes given earlier at the university, we emphasized and asked the student: “Try to explain by yourselves how detergents or boiling water remove lipids from food dishes?” In general, the models presented were similar to those presented in Figure 6, but as observed here, the students rarely represented the formation of micelles containing the lipids (for example, as presented here by the student of the scheme presented in Figure 6A).

2.2 Data analysis

The data were organized and analyzed using Bardin's Content Analysis [44], which consisted of three stages: (1) Pre-analysis, referring to the organization of the participants' responses; alphanumeric characters were used to identify the subjects, for example: A1, where “A” represents the word academic and “1” represents the alphabetical order of the names of the participants. Later, there was a floating reading of the material to be analyzed. (2) Exploration of the material, definition of the keywords or meanings found in the
text or drawings. And (3) Treatment of results, interpretation of the textual or illustrative content of the data obtained.

3 Results

3.1 Lipids and detergent interaction experiments

Students performed the experiments according to the availability of materials in their kitchens, so those detergents, types of lipids and containers used varied among participants. On average, each participant used about three different types of lipids (Table 1).

<table>
<thead>
<tr>
<th>Lipids of animal origin</th>
<th>Number of uses</th>
<th>Lipids of vegetable origin</th>
<th>Number of uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle fat</td>
<td>2</td>
<td>Karite butter</td>
<td>1</td>
</tr>
<tr>
<td>Butter</td>
<td>3</td>
<td>Canola oil</td>
<td>1</td>
</tr>
<tr>
<td>Chicken fat</td>
<td>3</td>
<td>Sunflower oil</td>
<td>2</td>
</tr>
<tr>
<td>Pork lard</td>
<td>5</td>
<td>Olive oil</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Margarine</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coconut oil</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soy oil</td>
<td>5</td>
</tr>
</tbody>
</table>

The lipids from vegetables were preferred over the animal's lipids. Soybean oil, which is very popular in Brazil, was the most used vegetable oil.

The analyses of students' reports are described below taking into account the main emerging topics.

3.1.1 Physical aspect of the samples

Two participants highlighted that the detergent was “consumed” along the 5-7 days of observations. For instance, student (A1) stated that detergent was “incorporated into” the fats (A3). In the case of A1, the experiments were carried out with soybean oil and pork lard. This participant concluded that the “detergent consumption” in her samples was equivalent to the emulsification process and was more evident in the experiment with pork lard (Figure 2).
Two participants identified changes in the color of the samples, which over the days became whiter and turbid (A5 and A7). One of them (A5), indicated the “dryness” in the sample with beef and chicken fat (Figure 3). These observations were similar to those made by A1. However, participants A5 and A7 did not discuss the possible causes for the observed events, they only described the observed changes.

A possible explanation for the “dryness” of the samples could be the evaporation of water from the commercial detergents and the formation of mixture between the detergent and fat (as described above by student A1 for pork lard and detergent). However, these
phenomena observed with different fats were not commented by the participants (as involving the evaporation and formation of a white solid; i.e., a mixture of fat plus SDS).

According to Fadhila, Ridlo and Indriyanti [45], many students find difficult to apply scientific knowledge to real observed situations. This problem has to be continuously worked out with students, at all levels of education, in order to instigate them to understand and apply Science as part of their lives [46]. Indeed, it would be important for them to break the stereotyped behavior and attitudes that links science only to the academic context of undergraduate classes. In addition, they should easily interpret and explain everyday phenomena using theoretical chemistry knowledge; however, it was not the case for the majority of students of our study.

Some students stated that some lipids solidified at room temperature (chicken fat, A4, A5; cattle fat, A5, A9; butter, A6; pork lard, A1, A9; butter and coconut oil, A9). However, only one participant mentioned why their sample solidified:

A9 – “On the other hand, coconut oil, despite having vegetable origin, would also have become solid at temperatures below 25°C, since it is composed mostly of the fatty acid lauric, a medium-chain triglyceride”. (Note that the student confounded fatty acid with triglyceride).

The fact that only one participant tried to explain the cause of the observed phenomenon indicated a common problem of superficial and poor interpretation of experimental activities. Similar results have been reported for high school and undergraduate students. In fact, students have extreme difficulty in observing and formulating their own interpretations of what they observed or could have observed [47], and are rarely willing to critically reflect about the activities they performed [48]. This may mean that students are taught and trained to “follow-the-recipe” methodologies and “cannot see without the teacher’s eyes”. In short, students observe what is indicated by the teacher or the protocol, but rarely have their own reasoning about observations or facts.

### 3.1.2 Categorization of conclusions/interpretations

The most frequent conclusion or interpretation made by the students were related to the “Cause of immiscibility between detergent and lipids”, “Concept of emulsification” and “Consequence of agitation of samples”.

For instance, since the samples were not mixed with the detergents, the formation of two phases was easily perceived and reported by eight of the nine participants. Six of them attributed this to the immiscibility between detergent and lipids. The reports covered
two categories: “Density difference” (A1, A5 and A6) and “Polarity difference” (A2, A4 and A8). For example:

(Density Difference) A1 – “The detergent and lipids are immiscible and form a heterogeneous two-phase mixture, the detergent is denser and is at the bottom”.

(Polarity Difference) A8 – “Since they are non-polar in nature, fats interacted with the non-polar part of the detergent, promoting a kind of separation”.

Possibly, the students who mentioned only the difference in density as the cause of immiscibility between the substances, based themselves on what they were observing macroscopically, without considering that the SDS has a polar and a non-polar portion. On the other hand, the participants who highlighted the difference in polarity as a cause, may have drawn their conclusions based on submicroscopic knowledge of SDS and lipids. However, the interpretation is alternative because, for instance, the student A8 stated that the apolar portions of the fat and detergent will interact, but this will separated them (“… promoting a kind of separation…”) and not form an emulsion or micelles. There are contradictions in the statements made. The students did not define that the detergent promotes the detergency of fats and that commercial detergents are diluted in water and the phases observed were probably the detergent (in water) and the fats that had not yet interacted, that is, without the agitation the emulsification or detergency of the fats by the SDS was slow.

According to Johnstone [36], chemical knowledge can be explained by the triangulation at 3 levels of perception: macroscopic, which can be seen; sub- or microscopically, referring to atoms, molecules, ions and “invisible” structures; and representative or mental explanations, which includes symbolic explanations (symbols, formulas, molarity, graphics, among others). Thus, to understand chemistry, it is necessary to move from the macro towards the submicroscopic levels (molecular and atomic), where the behavior of substances can be interpreted in terms of the invisible and translated into some representational language [36].

Considering the results presented here, it is clear that the participants in the present study were not yet able to explain the macroscopically observed phenomena at the submicroscopic and representative levels of understanding about the chemical interactions between lipids and SDS, or still cannot elaborate spontaneously a relatively simple chemical explanation (a model of lipid detergency by SDS). Therefore, it is essential to develop activities that also enable them to observe, interpret and explain macroscopically and molecularly the observed phenomena.
3.1.3 Emulsification Concept

Four of the nine participants referred directly or indirectly to the concept of emulsification in their conclusions. In general, they emphasized the interaction between the non-polar part of the detergent and lipids. For example: A3 – “The non-polar part of the detergent interacts with the fat, causing this fat to be dissolved (formation of micelles)

A micelle has a hydrophobic core formed by the interaction between the hydrophobic “tails” of soaps or detergents and some type of lipid. The hydrophilic “heads” of soaps or detergents cover the surface of the micelle. A suspension of micelles is called an emulsion [49,50]. By understanding this phenomenon, students should assimilate better and accommodate the knowledge into their mental schemes and should be able to apply it in real contexts. As in the case of the inactivation of SARS-CoV-2 by the action of soap, for example, knowing that a lipid bilayer involves the genetic material of the virus and that detergents are able to insert their hydrophobic tails into this structure, breaking it [50].

3.1.4 Comparison with Digestive Emulsification

Some participants (A2, A5 and A9) made a brief comparison between the emulsion observed in their samples and the digestive emulsification that occurs in our intestine. The following excerpt exemplifies the comparisons made:

A2 - "It is known that detergent has the ability to "break" oil molecules into smaller particles, so we can relate to what happens in our body, because the fats we ingest when digested with the bile present in our liver is able to act as a detergent, emulsifying these molecules and thus making their digestion easier”.

From this report, it is clear that some students correlated the phenomena observed in the experiments to events that occur in real situations of their lives. However, again it appears that this did not occur with the majority of participants. Generally, students have difficulty in formulating explanations or to provide support or critical points of evidence for their statements [51], so they choose not to formulate something that could “be wrong”. An Australian study, developed with 105 science pre-service teachers indicated that only 13% of them had advanced scientific reasoning skills, while 40% had basic reasoning skills [52].

3.1.5 Consequence of system agitation

Six participants found some type of change in the samples after shaking them, the most frequent were the formation of bubbles and the whitening of the mixtures. For exam-
ple, there is the report of the participant who stirred his experiment with chicken fat, after adding water: A8 – “With the addition of water and agitation of the medium, we can observe the characteristic formation of micelles trapping the fat in their interior”. Note that the A8 student was the one that before mixing stated… “Since they are non-polar in nature, fats interacted with the non-polar part of the detergent, promoting a kind of separation”. Figure 4 shows the images of this experiment before and after adding water and shaking the samples.

![Figure 4](image)

It was noticeable the formation of an emulsion after the addition of water and agitation of the samples that contained the fat and the detergent. This was not found in the control sample, without the detergent. It was observed that the participant in question was able to adequately use scientific knowledge about the concept of emulsification in view of the phenomenon observed in his experiment.

3.2 Soap action diagrams on SARS-CoV-2

For the second activity of the proposal, a material containing illustrations and theoretical explanations about the structure of SARS-CoV-2 (supplementary material - article page in the journal) was made available to the participants. Next, the participants have to build diagrams, illustrating the action of soap in the structure of SARS-CoV-2. Two participants (A7 and A8) preferred to describe the process, but most of them chose to draw pictures with textual explanations (A1, A2, A3, A4, A5, A6 and A9).

Five aspects were recurrent in the illustrations and descriptions constructed, namely: 1) Chemical structure of soap molecules, 2) Interaction of soap with the lipoprotein membrane of the virus, 3) Simultaneous interaction of soap with the membrane of the...
Educational Innovations: Perception of Pre-Service Chemistry Teachers about Detergency: From Macroscopic Observations to Symbolic Theoretical Mental models applied to inactivation of SARS-CoV-2 virus and water, 4) Rupture of the virus membrane, and 5) Water’s role in washing virus fragments.

Regarding the chemical structure of soap molecules, most participants (A1, A2, A3, A4, A5, A6 and A7) adequately highlighted that these molecules are made up of a polar (hydrophilic) and a non-polar (hydrophobic) part. The interaction of soap with the lipoprotein membrane of the virus was mentioned by all participants, emphasizing that the non-polar part of the soap molecule is “responsible” for this process. Participants (A2 and A6) who reported the simultaneous interaction of soap with the virus membrane and water, correctly pointed out that the non-polar part of the soap molecule interacts with the lipids of the virus membrane and the polar part with water. Such findings can be exemplified by the mental model constructed by A2 (Figure 5).

![Figure 5](image)

Figure 5. Scheme on the action of soap on the virus.

Although the scheme does not refer to the complete structure of the virus, it indicates the main steps in the action of the sanitizer, showing the interactions that occur between the detergent, the phospholipid bilayer of SARS-CoV-2 and water. According to Hsieh and Tsai [53], in addition to the potential to illustrate students' ideas and perspectives, drawings can serve as a means of transmitting messages that would not otherwise be possible. Thus, from Figure 6 one can see a good understanding of the participant about the inactivation of the virus with the use of soap and water/detergent, using the knowledge of chemistry and the biology of the virus. In general, the representations of other academics were also in this direction.

Viral membrane rupture was also highlighted by most participants (A1, A2, A5, A6, A7, A8 and A9). In general, the schemes indicated that the non-polar part of the soap molecules binds to the lipids of the virus membrane, causing a destabilization of this structure and subsequent rupture, deactivating the virus. Some academics (A1, A4 and A8) also emphasized that water also has the function of washing the virus fragments after the rupture of the viral membrane. Examples of these results are shown in Figure 6 (a and b).
Of note, only one student indicated the interaction of detergent apolar portion with the proteins found in the membrane of the virus (in the figure, the detergent is interacting only with one type of protein, Figure 6A). In fact, in the micelle formed, the student indicated interactions of the detergent with both the protein and lipids from the virus membrane.

**Figure 6.** Schemes of viral membrane rupture.

From the students’ representations, it can also be seen that the great majority of academics indicated only the presence of membrane lipoproteins and others only of membrane phospholipids. Maybe they still have not assimilated that they are different chemical structures (i.e., they are not synonymous). Thus, though they have different chemical composition and structures, that both are part of the virus's membrane and have hydrophobic portions that can potentially interact with the detergents. Therefore, the nonpolar portion of the detergent can interact with the hydrophobic region of both phospholipids and with hy-
drophobic portions of virus membrane proteins. The interactions will destabilize the structure of the viral membrane, causing the leakage of the internal content of the viral particle, preventing the virus from interacting with the cell and viral replication.

However, it can be seen that the participants were able to propose theoretical models or schemes to explain the basic processes of the inactivation of the virus with the use of soap. This can favor taking positive attitudes in the fighting against microorganisms, specifically with regard to hand hygiene, when washing with soap and water. However, these results contrast with data obtained in experiments with fats and commercial detergents, where the observations were only partially explained. A possible explanation for this discrepancy between the difficulty of interpreting emulsification in the experiments and the good explanation given about the detergent's action on the viral envelope is that the latter information is nowadays highlighted in the media. Thus, perhaps students are more likely to accept what is explained to them (even if only theoretically) than to use the ability to relate knowledge to explain an observed phenomenon.

4 Conclusion

In general, the data presented here indicated that simple problematized experimental activities with pre-service chemistry teachers associated with a relevant and contemporary problem of human society (the pandemic caused by SARS-CoV-2) could unravel some basic problems in the formation of future science teachers. Specifically, the pre-service teachers had limited capacity to explain at molecular and symbolic levels the interaction of lipids with a detergent (i.e., after the macroscopic observation of the phenomenon of detergency by themselves). In contrast, the majority of students gave partially satisfactory explanations to explain how detergents could inactivate the SARS-CoV-2. Together, the two activities (experimental and theoretical activities) indicate that students have fragmented knowledge about detergency and only when they were instigated to explain a nowadays-relevant problem, they were able to formulate a more coherent symbolic explanation about similar physicochemical processes.

In effect, it was evident that the pre-service teachers theoretically explained better the interaction of detergent with the viral particle than they explained the experimental interaction of detergent with lipids. Thus, the inclusion of some apparently trivial and macroscopically observable chemical experiments can instigate pre-service teachers to use their scientific reasoning under real circumstances of their lives. Such type of simple experimentation can favor the development of scientific literacy in the pre-service teachers, specifi-
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cally, basic aspects of scientific literacy, such as the explanation of daily phenomena scientifically.

We also believe that it was an opportunity to demonstrate to participants alternative and simple teaching methods [54], outside the traditional (expository mode), using dynamic and active approaches. Also, as stated by some students, the simplicity of the materials used and in alternative spaces, such as their own homes, demonstrated the applicability of such type of activities in the school scenario. It is understood that such type of activities can empower pre-service teachers with technical tools regarding approaches to teach chemistry more efficiently under different teaching situations. In this sense, it is imperative to advise pre-service teachers about the importance of adopting alternative teaching postures to the traditional approaches, even if only a little, in order to increase the quality of the teaching and learning processes.

Furthermore, it was possible to identify that various participant have difficulty in interpreting the observed phenomena, developing hypotheses, formulating explanations based on scientific reasoning, correlating specific knowledge of chemistry or biochemistry with real everyday situations, among other problems. Perhaps, the problem is due to numerous factors, which are not only correlated with students. Indeed, during their undergraduate formation, they are not encouraged to develop or exercise such skills. Thus, they end up developing a “stereotyped behavior of seeing what the teacher sees”. They incorporate the beliefs that their roles as a teacher are to give right answers, without critically reflecting about simple observed phenomena.

This cyclical problem is present at all levels of education and in many educational institutions, which permeates Basic Education (elementary and high school), Higher Education, and returns to Basic Education through newly trained teachers. The challenge is to transform this reality. Here, we emphasize that scientific literacy should be an essential path of science learning, particularly to go beyond just to learn superficially and reproduce scientific knowledge in a precarious way. Regarding experimental activities, the improvements in scientific literacy can be achieved only if the activities go beyond the systematic “follow-the-receipt protocol” involving uncritical manipulation of materials and substances, towards practices that involve the recruitment of high cognitive functions (planning, observation, reasoning, interpretation, decision making, etc.) and attitudinal aspects of students, discussed below.

In general terms, the current meaning of scientific literacy refers to the role of Science as a tool for social change and transformation, in the detriment of a perspective focused on the memorization of scientific concepts and laws [2]. In other words, a scientifi-
Educationally literate individual is not one who masters only the specific content of Science, but one who has the ability to apply scientific knowledge in their reality, to make decisions, explain certain phenomena, take care of individual and collective health, think critically, among others.

Scientific literacy provides better conditions to understand Science in a broad way and favors numerous interconnection and contextualization with the real world, enabling the improvement of the subjects' quality of life. In this sense, we understand that experimental activities, in addition to facilitating learning in Science, can be useful tools to promote scientific literacy to students of any educational level. Therefore, it is important that scientific learning is built with the contribution of experiments that prioritize an investigative posture, questioning and not reproducing information, content, such as the "follow-the-recipe" methodology [55].

Promoting an investigative and questioning attitude in students through experimental activities, for example, can contribute to the development of a more autonomous, reflective, critical, thinking, observant and proactive behavior in the subjects. This is of paramount importance as it contributes to the social and citizen formation of individuals, as it provides them with a basis to face new situations in which they need to take initiatives, within or outside the educational scope. In fact, activities aimed at stimulating citizenship can help the subjects in social life and their individual demands in several aspects. For instance, the remote teaching of biochemistry using various alternative methodologies, involving activities related to the students' daily life have recently been reported [56]. The authors indicated that the participation of the students was strengthened, which is expected to increase learning about biochemistry.

Although it is not appropriate to make generalizations, considering the sample size of this study, our results suggest that there is a need for more practical and problematized work involving the observations of simple chemical phenomena with pre-service chemistry teachers (and with other pre-service natural science teachers). The simple activities have the potential to favor critical and reflective thinking, scientific reasoning, the ability to formulate hypotheses, interpret and explain phenomena based on the macroscopic observation and scientific knowledge. Consequently, enabling the development of scientific literacy of the learners. In fact, the deficiencies in explaining the interaction of commercial detergents with fats contrasted with adequate explanations about the detergent's interaction with the structure of SARS-CoV-2. This reinforces that student are familiarized with abstract theoretical situations, but cannot interpret relatively simple macroscopic and submicroscopic experimental phenomena, such as the detergency they observed.
Finally, it emphasizes that this educational proposal can be applied in High School and in courses in the area of Natural Sciences in other academic fields. The objectives proposed here can be reformulated according to the particularities and demands of each context, and can be an alternative for teaching biochemistry, also in times of remote education.

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