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Chewing Gum and pH Level of the Mouth: A Model-based Inquiry Sequence to Promote Scientific Practices

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Abstract Television ads usually use scientific messages to highlight the benefits of the products they advertise. This is the case of a known brand of chewing gum that "helps to increase the oral pH after meals". From this starting point, we have developed a short sequence of activities (*sensopills* for 1.5h) with a Model-Based Inquiry teaching approach to engage students in scientific practices, and understand disciplinary core ideas and crosscutting concepts in order to promote critical consumers of information about science, as NRC recommend. We use a historical acid/base model (Lemery) to explain and predict oral pH phenomena. The *sensopill* "chewing gum" has been implemented with hundreds of secondary school students. Learning self-regulation results show that students recognized having learned the difference between dilution and neutralization and the concept of pH and their improvement at some scientific inquiry skills such as hypothesis formulation and data collection.

Keywords: *acids / bases, historical models, inquiry-Based teaching, modelling, learning-teaching sequence*

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1. Introduction

Proposals of activity sequences focused on acid-base contents have an extended tradition in Chemical Education. Studies performed by Nakhleh [1], Carlton [2], provide a variety of activities on what acid-base models are. More recently, this matter can be found in different pieces of work [3], where ICTs are included [4], and providing depth to the ideas shown by the students [5]. Furthermore, most of the recent proposals are focused on working in inquiry by using Acid-Base Chemistry [6]. Since The National Science Education Standards [7] proposed the structure of inquiry-based science education (IBSE) it has been detected a polysemy in the term [8] and a higher number of *hands-on* activities proposals. For that, the NRC [9] emphasizes the need to promote 'scientific practices' in response to the increased flood of proposals with a reduced view to *hands-on* activities ignoring the importance of *minds-on* activities. That is, to *engage students with the practices, crosscutting concepts, and core ideas of science in order to develop critical thinkers and consumers [9]*.

1.1. Objective

In this paper we want to propose a teaching sequence by using pH-meters [10] for secondary school (12-18 years old students), where the IBSE approach is combined with the construction of a model to explain and predict the acid-base phenomena. As research has shown, inquiry-based teaching has a positive effect on student learning, particularly students' engagement in the cognitive dimensions of inquiry and teacher led inquiry activities [12]. To achieve this, our research group (@Sensociencia) focuses on designing and testing short sequences of activities (1.5h approx.) that we named *SENSopills*; learning pills with *SENSe, SENSors and SENSations*. The Sensopill addressed in this paper used a television advert of a *chewing gum*, which suggests that when the gum is chewed, pH of the mouth increases, improving the benefits for oral health.

The main objective of this Sensopill is to allow students to differentiate between acid dilution and neutralization. In order to achieve this, in the first part of the Sensopill (focused on *hands-on* activities) we incorporate a model that explains both dilution and acid-base neutralization. Lemery's historical model [12] is used, transformed into PACMANs (base), triangles (acid) and circles (neutral, water or red cabbage).

2. Teaching Sequence: Chewing Gum and pH Level of the Mouth

In addition to the conceptual learning objective (understanding the difference between acid dilution and neutralization), with the teaching sequence we aim a procedural objective too, apart from promoting the inquiry skills development in the students, aiding them to be aware of this procedural knowledge constructed. Students are engaged in questioning [13], expressing, justifying, and discussing their ideas by using different forms of communication (oral and written language, graphics, drawings…), designing the search for evidence to contrast with their own ideas, carrying out research, analyzing results, obtaining and discussing conclusions about the results and the process followed. Along this process, students recognize the need for a model to explain, they express and use an initial model, evaluate their models, review them, express a final model and use it to explain new phenomena [14].

Therefore, teaching sequence is divided into two parts, that are well differentiated for the students, the first one engaging the students (IBSE) and the second one the modelling (Lemery's historical model). Teaching sequence starts with a question that engages: *A TV advert (Orbit™) informs the viewers that after every meal acidity in the mouth increases and can damage tooth enamel. Do you know any acidic substance? List three acid substances. How do you know that they are acid? How can we prove that they are acid without tasting them?* The expression of students' ideas drives the discussion on two or three hypotheses:

- When we chew, we generate more saliva, so it promotes (DILUTION).
- Chewing carries a substance that NEUTRALIZES acid elements.
- Chewing gum ADSORPTION, others like chewing gum warms and destroys bacteria.

After the communication and discussion, the strongest point of this sequence starts: *How could you know if your hypothesis conforms with reality? Details the experimental design to follow and discuss with members of your group the results you expect to get*. We want to mention to the teachers who apply this sequence the importance of stopping at this point, student's groups usually propose different experimental designs that need a collective debate to analyse if their experimental designs measure what they want to measure and if they control the variables well, previously to the search for evidence – real-time data and the analysis of results: does this match what you expected? Do the results match the chewing gum ad graph? As graphics do not usually coincide the pH of toothpaste in water is measured and then toothpaste is added to the water/vinegar mixture.

In initial levels of secondary school (12-14 years old) this fragment of teaching sequence could be enough. However, we want to emphasize the need to construct a model that let the students explain phenomena (dilution and neutralization) and is useful to predict other processes such as why a balloon inflates when bicarbonate (from ballon) is added to vinegar in a bottle.

Considering the need to incorporate all the inquiry-based teaching characteristics [7] with special emphasis on *minds-on* activities, we opt to promote the dilution (colour fading) and neutralization understandings by using Lemery's model. To recognize the need for a model, students must express and use their initial models, that is why we ask them to explain what they imagine is happening in the glass with the aid of a picture: when there is only water, when we add vinegar, and when we add baking soda to the diluted vinegar. After that, students have to evaluate and review their initial models (Figure 1): Are they useful to explain why the pH decreases when vinegar is added?

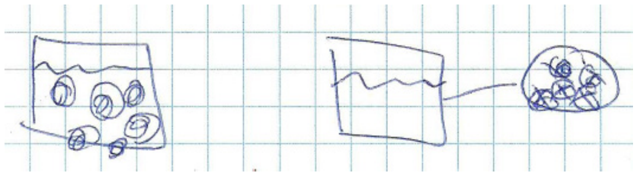

Figure 1. Initial student's model [1]

To distinguish between dilution (colour fading) and neutralization we can use Lemery's model [12], renaming it as 'PAC-MAN' model so that it is closer and familiar to the students. In this model, water (neutral) is represented by a blue circle, and as we also use red cabbage extract as pH indicator, it is represented by purple circles which means a neutral medium; acids are represented by red triangles (color to which the red cabbage turns into acid medium), and bases as green "PAC-MAN". The combination of triangle and PAC-MAN would result in circles -neutral-(Figure 2).

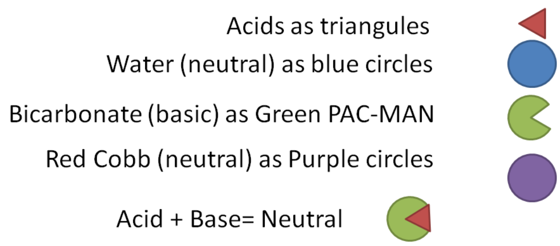

Figure 2. PACMAN's acid-base model

Then, students are able to construct a final model and use it to explain new phenomena, even when they are asked for a new phenomenon to draw the limits of the 'PAC-MAN' model: *Could we explain why a balloon inflates with the 'PAC-MAN' model?* PAC-MAN model allows to explain acid-base processes in dilution, but is not useful to explain gas formations. A secondary school student proposed to add "bow ties" to PAC-MAN that would be released when the latter reactions with triangle and inflates the balloon (Figure 3).

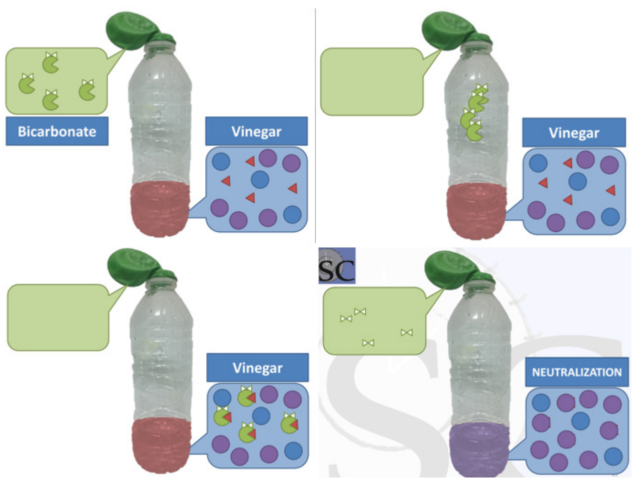

Figure 3. Improved model capable of explaining acid-base process with a gas involved

[1] Due to ethical reasons, regular teacher of the students participating in our research informed their parents, who gave their consent and authorization of the educational diffusion of the results preserving anonymity of the students.

Despite the explanatory power of PAC-MAN model recognized by the teachers, many of them might think that these models can hinder the students' learning of other more sophisticated models (Arrhenius, Brönsted-Lowry or Lewis acid-base models). However, it is important to highlight that we offer a modification of the model to introduce chemical formulation, and making it meangniful to the students, by using the PAC-MAN model as a link between the acid and alkaline particles consideration and the chemical formulation (Figure 4).

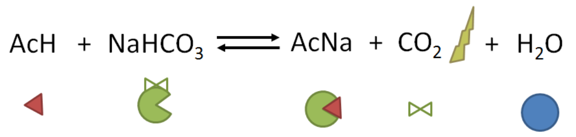

Figure 4. Correspondence between the PAC-MAN model elements and chemical formulation

3. Results

The sequence of activities described in the present paper shows that it is possible to attend to the indications of giving importance to *minds-on* activities in IBSE approach [9] without it necessarily implying an excessive extent of time (1.5h) with the sequence presented in this paper. To check if the sequences of activities make sense, it has been done with students organized in groups of four, several times (Table 1) in punctual teaching, isolated from other chemical content in their curriculum and with students that had not received any teaching about acid-base reactions previously.

This sequence of activities has been evaluated under several dimensions (cognitive, inquiry skills, modelling, emotions). Here, we highlight the results obtained in KPSI questionnaire applied at the end of the sequence, where students self-regulated their own learning (Table 2).

Table 1. Students participating in Chewing gum Sensopill

Secondary school (date)	Group (time) Age	Nº students	Total time (sec)
Turaniana (7th April)	1st Bac. (11:45-12:45) 17 years old	11	3175
Turaniana (2nd May)	3rd ESO (14:00-15:00) 16 years old	20	1528
Turaniana (8th May)	3rd ESO (11:45-12:45) 17 years old	20	2827
Murgi (5th June)	2nd ESO (09:15-11:00) 15 years old	32	4826
Murgi (5th July)	3rd ESO (11:45-13:00) 16 years old	24	5296
Total		107	

Table 2. KPSI results

Knowledge about…	Before (%, sd)	After (%, sd)	Effect size (%, sd)
Which substances are acid	(2.23, 1.06)	(3.90, 0.93)	(1.67, 1.12)
How we can check that they are acid	(1.78, 0.92)	(3.90, 1.00)	(2.12, 1.04)
What pH is and how it is measured	(1.58, 0.83)	(3.93, 1.06)	(**2.35**, 1.30)
Hypotheses about the effect of the chewing gum on oral pH	(1.60. 1.08)	(3.92, 1.12)	(**2.32**, 1.39)
Designing experiments to contrast hypotheses	(1.67, 0.89)	(3.65, 1.16)	(1.98, 1.26)
Representing graphically hypotheses and interpretations	(1.65, 0.95)	(3.40, 1.08)	(1.75, 1.14)
Data collection with a pH meter	(1.56, 0.96)	(3.95, 1.08)	(**2.38**, 1.32)
Data analysis (coincidences and discrepancies)	(1.77, 1.08)	(3.40, 1.14)	(1.63, 1.01)
Chewing gum: diluting or neutralizing acids	(1.56, 1.01)	(3.95, 1.17)	(**2.36**, 1.38)
"Pac-man" model to explain why pH decreases in the mouth after Chewing gum	(1.64, 1.05)	(3.36, 1.38)	(1.72, 1.45)
"Pac-man" model to explain why a balloon inflates (baking soda + vinegar)	(1.47, 0.89)	(3.23, 1.37)	(1.76, 1.38)

Our results reveal two issues: this topic is close to the students, since all of them recognized that before the application of the sequence they knew something related to each idea (before > 1). Also, in those items where they recognized having learned more (in bold), the results highlight that the sequence of activities helps secondary students to differentiate between neutralization (neutral medium) and dilution, as well as an improvement in their inquiry skills (data collection with a pH meter).

Acknowledgments

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