PCK by CoRes and PaP-eRs for Teaching Acids and Bases at High School

Andoni Garritz[1], Clara Alvarado[2], Florentina Cañada[3] and Vicente Mellado[3]

1 Facultad de Quimica, Universidad Nacional Autonoma de Mexico, Mexico
E-mail of the speaker: andoni@unam.mx
2 Centro de Ciencias Aplicadas y Desarrollo Tecnologico, Universidad Nacional Autonoma de Mexico, Mexico
3 Facultad de Educacion, Universidad de Extremadura, Spain

Abstract

The central purpose of documenting the knowledge, skills, beliefs, etc., of ten Mexican teachers, with experience in teaching Acidity and Basicity in high school, was to know how they design, prepare and organize their classes, in order to enable and facilitate an action-research to design, develop and evaluate a teaching-learning sequence (TLS) of acidity and basicity, for high school, within the constructivist framework.

Two tools presented by Loughran et al. (2004) Content Representation (CoRe) and Pedagogical and Professional experience Repertoire (PaP-eRs), were selected as instruments to capture the PCK of those ten teachers.

The main objective was to select the consensus "central concepts" the teachers often mentioned for the topic. Also it was important to document conceptual (historical aspects, importance of learning, relationship with the daily environment, difficulties in the teaching-learning process, procedures and resources to motivate students and evaluation), procedural and attitudinal contents.

They wrote in their CoRes not only the concepts they considered central to the subject; but for each one of them the teaching objectives; knowledge of alternative conceptions of students and their learning difficulties; the appropriate sequencing of topics; the correct use of analogies and examples; ways to address the central ideas, experiments, projects and problems that the teacher used during class; ingenious ways of evaluating student progress and understanding.

The PaP-eR was developed by transcribing the recording of eight sessions of class with one of the teachers surveyed with the CoRe and a second teacher in training, and writing a large summary of what was developed during these sessions.

An important conclusion reached after attending these sessions, was that it was necessary to strengthen the teaching and learning of acidity and basicity at the macroscopic level, as a result of a poor knowledge about this subject that was perceived among students.

Finally, with respect to the teaching and professional profile of teachers, we can say that six teachers were centered on students and in their learning difficulties, with diversified teaching activities; the other four, were centered on the teacher and disciplinary content, with a transmissive approach to teaching.

PCK information obtained from Mexican teachers was "triangled" with alternative conceptions and learning difficulties of a sample of 388 Mexican students of the high school level; with the content on acids and bases chapter of eight textbooks frequently used in secondary chemistry schools in Mexico; with the curriculum of middle and high school chemistry in which the subject acidity and basicity is taught; with the alternative conceptions and learning difficulties reported in the literature on teaching and learning the subject; and with university and school level chemistry textbooks in their acid-base chapters.

Keywords:

Pedagogical content knowledge, Content Representation, Acids and bases, High school, characteristics and strategies of teaching, Chemistry teaching and learning, In-service science teacher classroom observation.

Introduction

It is important to remember that teachers are one of the main variables in the teaching/learning of science, primarily with students, syllabus, textbooks, laboratories (Mellado, 1998) and now information and communication technologies. Present strategies used in the classroom currently recommend the teacher to be a mediator, a counselor, for his/her students to acquire knowledge meaningfully.

The teacher should organize and structure the program contents, select the representations to be used, choose the central ideas of the lectured topic, so that students –when introduced into a variety of strategies and processes– can generate and process information that ultimately are conducive to learning; that is, allowing their cognitive experience to further develop their ability to learn. The teacher should aim to achieve a goal of academic success for each one of their students and help them to find a full school meaning.

Teacher performance in the classroom is one of the most important factors in students' academic achievement, which in the short and medium term results in better life and job opportunities for them; this performance has become increasingly professionalized (Park and Oliver, 2008), and social transformations and the complex characteristics of teaching, require more preparation and pedagogical expertise to significantly impact their education.

Research on the conceptions and practice of teachers is one of the main topics of the research agenda in science education (Tobin *et al*, 1994; Tobin, 1998; Mellado *et al.*, 2006, Porlán *et al.*, 2010; 2011). However, except for the case of Drechsler and van Driel (2008, 2009), the PCK of acidity and basicity has not been extensively investigated, although the contribution to the misunderstanding of various concepts related it has often been mentioned as alternative conceptions on this topic (Bardanca *et al.,* 1993; Cros *et al.,* 1986; 1988; Garnett *et al.,* 1995; Griffiths and Preston, 1992; Jiménez-Liso *et al.,* 2000; 2001; Jiménez-Liso and De Manuel, 2002; Kind, 2004; Ross and Munby, 1991; Vázquez-Alonso, 1990).

Porlán and Martin del Pozo (2004) express the importance of knowing the scientific conceptions of teachers, because these:

a) Have a relationship with the dominant model of teaching and also with what is meant by teaching;

b) Keep some relationship with the conceptions referring to how students learn science;

c) Help constructing the dominant scientific myths in our society: the myth of scientific progress, as well as the infallibility of scientists and experts;

d) Influence on the students' scientific conceptions; and

e) Help building and/or strengthening the image of science to the general public.

Science teachers undoubtedly must possess as a prerequisite a thorough knowledge of the subject, however, it is also necessary that they possess diverse professional tools that go beyond those usually studied in college (Fernández *et al*., 2002; Shulman, 1987).

Regarding the aspects relative to the quality of teaching, Brophy (2001), a renowned researcher of education, has focused on what teachers should be evaluated. Quoting Shulman (1986), and his PCK concept, Brophy says Shulman has argued convincingly that to train teachers we must divert attention from the more generic approaches to more specific instructional methods. In his introduction to the book *Subject-specific instructional methods and Activities*, speaks of "The twelve guidelines of good teaching", the result of decades of research on the behavior of good teachers. The basics of these guidelines for a better understanding by students happen (Brophy, 2001, pp. 6-21):

a) When students are in communities with a supportive climate in the classroom;

b) When most of the available time students are involved in activities related to the curriculum and the classroom management system emphasizes students' engagement in those activities;

c) When all curricula are aligned to the accomplishment of instructional purposes;

d) When teachers guide and prepare students for learning, giving an initial structure to clarify the expected outcomes and the key learning strategies desired;

e) When the content is explained clearly and developed with emphasis on their structure and connections;

f) When questions are planned to engage students in sustained discourse structured around powerful ideas;

g) When students are given the sufficient opportunities to practice and apply what they are learning and feedback oriented to improve it;

h) When the teacher assists students, as they need it to achieve their productive engagement with learning activities;

i) When the teacher models and instructs students in learning and self-regulation strategies;
j) When the teacher promotes cooperative learning, because students often benefit from working in pairs or small groups to build understandings or to assist another to master the skills;
k) When using a variety of methods of formal and informal assessment to monitor progress toward learning goals;
l) When the teacher establishes and follows through on appropriate expectations for learning outcomes.

The Pedagogical Content Knowledge, its portraying and documentation.

Pedagogical Content Knowledge (PCK) is the set of beliefs and knowledge possessed by teachers that can be considered as a bridge between pedagogical aspects and the specific content to be taught, which can be useful for the preparation and updating of science teachers, that traditionally has focused only on content knowledge. It provides the ability to translate the contents to a diverse group of students, using multiple strategies, instructional methods and representations, considering the contextual, cultural and social limitations, within the learning environment. Although there are generic skills to teach, many of the teaching skills of outstanding teachers are about some specific content –people, for example, says, "He is an outstanding English teacher" or "She is an excellent Biology teacher"- that is to say, it is part of PCK (Geddis *et al.,* 1993).

In a recent meeting (The PCK Summit) in Colorado Springs, USA, in October 2012, a set of experts on PCK were discussing about definitions, applications and interpretations of this construct, and the following description was proposed by one of the groups under discussion: PCK is "knowledge and beliefs for a given teacher to teach a particular topic in a particular way for particular students for particular reasons to enhance students' outcome". The four times that the word "particular" appears in this definition is a double-edged sword. On one hand, it means that PCK must be constructed specifically almost each time a given teacher within some objectives has to proceed lecturing a precise topic to certain set of students with a definite background and learning characteristics. But on the other, it represents a superb challenge, being PCK an academic construct that represents an intriguing idea, rooted in the belief that teaching requires much more than delivering content knowledge to students, which includes the purposes involved and the best ways to represent and evaluate that knowledge.

In a presentation parallel to this on the ESERA-2013 Conference, PCK is defined another time with the four “particular” in the following way: “personal attribute of a teacher, considered both a knowledge base and an action. It is the knowledge of, reasoning behind, planning for, and enactment of teaching a particular topic in a particular way for a particular reason to particular students for enhanced student outcomes” (Gess-Newsome and Carlson, 2013).

Shulman (1986) proposed and developed the PCK with colleagues in the project "Knowledge Growth in Teaching", as a model for understanding teaching and learning. The project studied how novice teachers acquire new understanding of the content and how this influences their teaching. Shuman introduced it as PCK: the result on the interaction between the thematic content of the discipline and pedagogy. He considered it as part of the knowledge base for teaching, which describes the ability of teachers to help students understand a specific topic. Shulman considered that the key factors of PCK were:

a) Using representations of knowledge on the subject; and

b) Understanding specific learning difficulties, and the conceptions and preconceptions of students.

Shulman also recognized three categories of content knowledge:

1) Subject Matter Content Knowledge;
2) Pedagogical Content Knowledge;
3) Curricular Knowledge.

Shulman (1986; 1987) defined PCK as the way of representing and formulating the subject content to make it more understandable to others, and he said it was the knowledge that goes beyond the subject matter *per se* and reaches the dimension of subject matter knowledge *for teaching*. PCK is different from general pedagogical knowledge for teaching, which includes generic principles of organization and management in the classroom, and knowledge of the general theories and methods of teaching.

PCK enables the teacher to answer questions like: “What analogies, metaphors, examples, laboratory demonstrations, simulations, are the most effective ways to communicate the appropriate understandings or attitudes of this topic to students with particular background?" (Shulman and Sykes, 1986, p. 9), that is, the effort made by the teacher to understand and make understand a particular topic. It also includes comprehension of what facilitates or hinders learning that specific content, and the conceptions and preconceptions that students of different ages and backgrounds have access to learning the topics most frequently taught in the lessons.

As Wolfgang Klafki (1958) anticipated in his book on classes' instruction, one can summarize that PCK includes all of the representations mentioned in the following questions posed to the teacher (see Klafki 1995 for an English written reference):

- What basic phenomenon or fundamental principle, what law, criterion, problem, method, technique or attitude can be grasped by dealing with this content?
- What significance does the content in question or the experience, knowledge, ability or skill to be acquired through this topic already possess in the minds of the children in my class?
- What facts, phenomena, situations, experiments, controversies, etc. in other words what intuitions are appropriate to induce the child to ask questions directed at the essence and structure of the content in question?
- What pictures, hints, situations, observations, accounts, experiments, models are appropriate in helping children to answer, as independently as possible, their questions directed at the essentials of the matter?

Shulman (1987, p. 8) said about PCK: "It represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction". He expanded the notion of basic knowledge that the teacher should have, adding another four types of knowledge (p. 10):

a) General Pedagogical Knowledge, with special reference to those broad principles and strategies of classroom management and organization that appear to transcend subject matter;
b) Knowledge of learners and their characteristics, including their learning difficulties of the subject content;

c) Knowledge of educational context, i.e., workings of the group or classroom, the character of communities and cultures;
d) Knowledge of the ends, purposes and values and their philosophical and historical grounds, which was afterwards referred as “Orientations” by Magnusson *et al.* (1999).

Shulman (1987, p. 15) also develops a model for pedagogical reasoning and action, a diagram of which is presented in figure 1. This diagram shows how teachers proceed each time they have to give lecture(s) on a specific topic, starting from comprehending the content, transforming it in intelligent representations, selecting them from their repertoire, and adapting them to the actual student characteristics. The second stage is a cycle in which the instruction is followed by its evaluation, the revision of the class’s performance and a new set of comprehensions in a spiral trajectory, now over the first one that started this figure.

The idea of PCK was enticing because it seemed to be such a clever way of imagining what the specialist knowledge of teaching might involve. PCK is complex and usually so deeply a part of a teacher’s intrinsic practice that it is tacit and, more often than not, largely inaccessible (Kind, 2009). The difficulties allied to making more use of PCK lies in its elusive nature. PCK conjured up an image of cutting-edge knowledge of practice, something special and important, something that could define expertise, something that could illustrate in a meaningful way why teaching needed to be better understood and more highly valued. PCK is the knowledge and beliefs that teachers develop over time, and through experience, about how to teach particular content in particular ways in order to enhance student understanding (Loughran *et al.,* 2012, Preface).

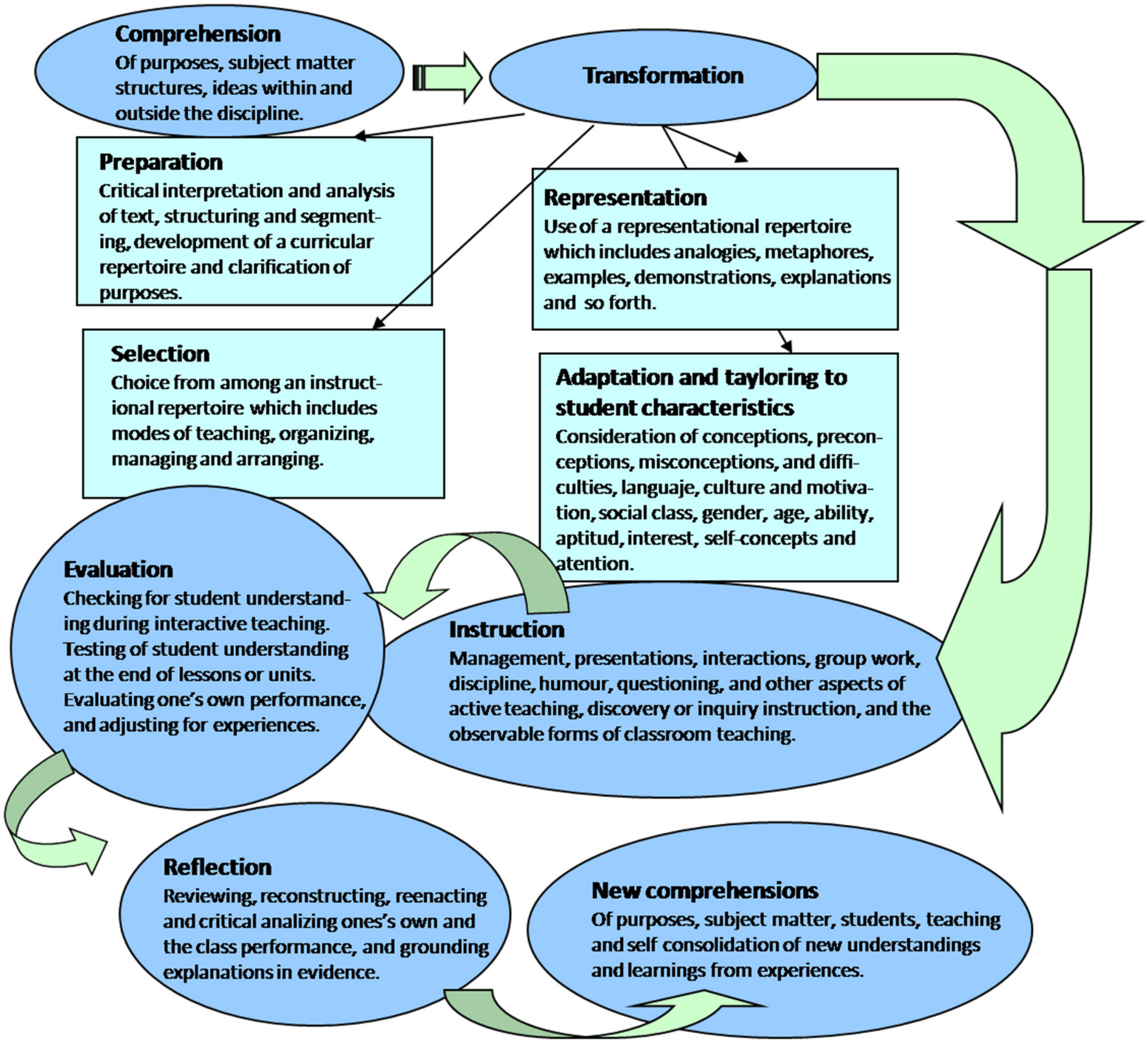


Figure 1. This information was proposed by Shulman (1987) in "Table 1. A model of pedagogical reasoning and action". It was adapted to a diagram by Salazar (2005).

PCK has been a topic in which much research has been conducted and reviewed. Some relevant publications are:

- Gess-Newsome and Lederman (1999), an interesting book that joins the description of several visions of PCK, the ways of assessing and measuring the construct and the impact on science teacher education programs;
- de Jong, *et al.* (2002), a review of the work written about PCK in the chemistry education context;
- Hashweh (2005), a paper conceiving a reconstruction or new conceptualization of PCK as teacher pedagogical constructions;

- Abell (2007), a throughout review written for the *Handbook of Research on Science Education*;
- Miller (2007), a review considering the history, the categories of teacher knowledge, the assumptions, and methodologies for investigating PCK;
- Park and Oliver (2008), a paper considering six explicit elements of PCK, including an affective one, the “Teacher Efficacy”;
- Abell (2008) the author defend the actuality of research about PCK; and
- Kind (2009), the last unabridged review on the construct.

Nowadays PCK has also been related for ICT teaching and learning (Khan 2011; Hughes and Scharber 2008).

In the Spanish speaking word the concept was introduced almost simultaneously in the Universities of Sevilla, Granada and Extremadura in Spain by (Marcelo 1993; Bolívar, 1993; Mellado and Carracedo 1993, respectively), as «Conocimiento didáctico del contenido» [Didactic Content Knowledge] and by Garritz and Trinidad (2004) in Latin-America, as «Conocimiento Pedagógico del Contenido» [Pedagogical Content Knowledge]. In another paper Garritz et al. (2008) resume their researches in the field of pedagogical chemistry knowledge and his most recent research in another one (Garritz, 2011).

Magnusson *et al.* (1999) have declared a set of five components of PCK (see figure 2). It has to be overemphasized that *beliefs* are mentioned in almost all of the components, except in the “Orientations” one, but recently, Friedrichsen *et al.* (2011, pp. 358-359), given the multiple descriptions this term has received, have defined this component as “a set of beliefs with the following dimensions: goals and purposes of science teaching, views of science, and beliefs about science teaching and learning”. Summarizing, beliefs and knowledge permeate all components of PCK.

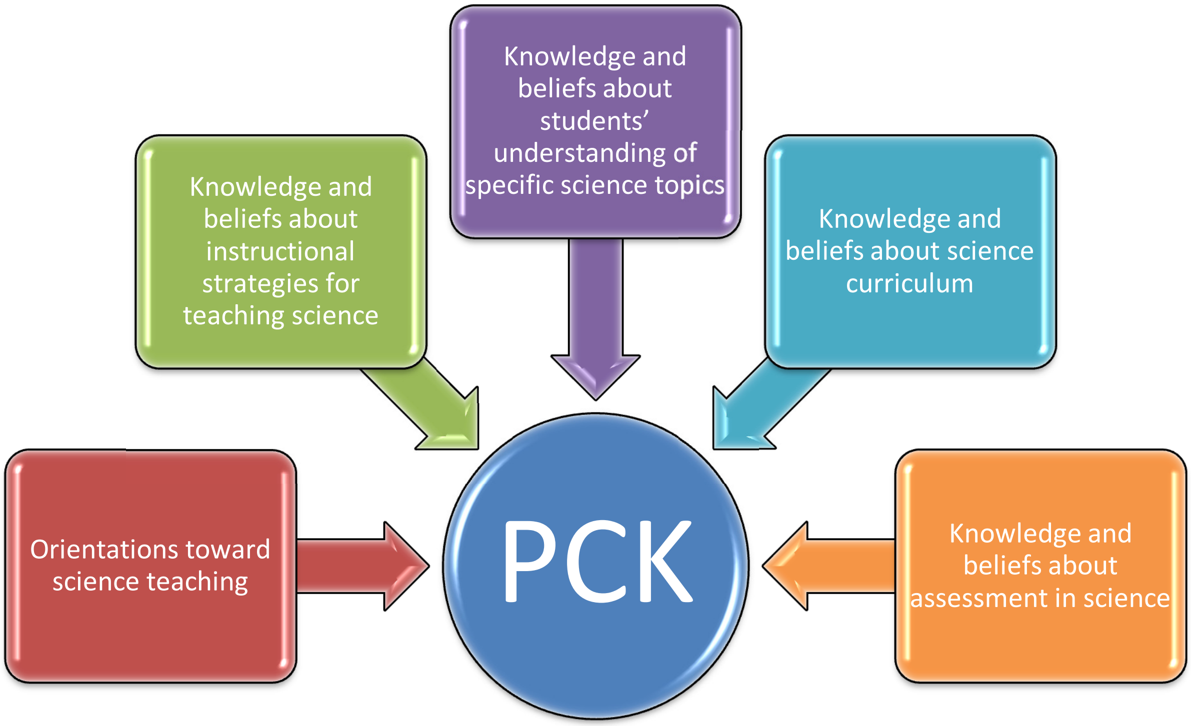


Figure 2. The five components of PCK according to Magnusson et al (1999). It has to be mentioned that these authors made a diagram in which the "Orientations" box was connected with the other four components, because it refers to "purposes and goals for teaching science at a particular grade level". In this chapter it has been presented as one of the five components without making any emphasis on it, as it is also shown by Morine-Dershimer and Kent (1999, see figure 1 there).

In our project, a central purpose of documenting the knowledge, skills, beliefs, etc., of a set of Mexican high school teachers, was to know how they design, prepare and organize their classes inside and outside the classroom. The final interest was to conduct an action-research to enable and facilitate the design, development, evaluation and redesign of a teaching-learning sequence (TLS) on acidity and basicity, for his level, within the constructivist framework (Alvarado, 2012). The overall idea was to help the training and updating of teachers and enrich the delivery of content in the classroom, avoiding if possible, the monotony of the lectures, allowing the guide of students in the classroom and laboratory to understand the subject in a way personally meaningful to them.

After reviewing articles on the characteristics of the "good" teachers (Tobin and Fraser, 1990; Brophy, 2001; Tobin, 2006; Davidowitz and Rollnick, 2011), we decided capturing and documenting PCK of ten Mexican high school teachers. Their experience with high school students would contribute to the available knowledge for teaching and the alternative conceptions their students have on the topic. Its documentation, and dissemination would be valuable, because we selected the teachers considered "great" teachers both by their peers and by the students themselves. A résumé of the characteristics of the ten teachers will be presented in the CoRe part of "Results and Discussion" section of this study, after analyzing the outcomes.

As has been mentioned, PCK is complex and usually so deeply a part of a teacher's intrinsic practice that it is tacit and, more often than not, largely inaccessible (Baxter and Lederman 1999). To capture and document the PCK, Loughran *et al.* (2004) proposed two complementary methodological strategies:

- The Content Representation (CoRe), using a questionnaire as framework.
- Pedagogical and Professional experience Repertoire (PaP-eR), through classroom observation and video recording of acidity and basicity teaching, by one of the teachers surveyed and another in training.

Content Representation

The CoRe provides a vision of how teachers approach the teaching of certain subject to a specific group of students, it provides the reasons linking how, why and what of teaching that content. It includes the role of beliefs and contextual factors in the understanding and practice of teachers (Tobin *et al.*, 1994).

A CoRe is a tabular description of the "big ideas" or "central concepts" of the subject, versus:

1. The goals of education;
2. Why it is important for the students to know these concepts;
3. What they need to learn about each concept;
4. The teacher knowledge about students' alternative conceptions and their common problems of learning that concept;
5. Effective sequencing of the teaching contents and the most important representations used to frame the concept;
6. The proper use of analogies, demonstrations and examples, and finally
7. The assessment forms used to display the progress of the group.

CoRe structure has the potential to help problematizing the content and teaching approaches in the minds of teachers, and provoke the thinking about what is important in teaching the subject and why. Even helps teachers to identify what they need to know and think about when teaching a new subject.

For Kind (2009), the CoRe of Loughran *et al.* (2004) offer the most useful technique to capture and record directly teachers' PCK. This method is clearly focused on the knowledge and tools for teachers, and a CoRe provides a powerful resource to record the work of an experienced teacher, useful to exemplify good practice. However, this method is not unproblematic: the daunting task of completing it by some teachers, for example, the lack of confidence in their abilities, and the large time taken to complete it. The group of Rollnick (2008) also uses this methodology.

Pedagogical and professional experience Repertoires

Loughran *et al.* (2004) state that the PaP-eRs are a window into a teaching-learning situation, where content shapes the didactic action in the classroom conducted by the teacher, and are based on *in situ* observations or in comments made by him/her during the interviews in which the CoRe is developed. The PaP-eRs are consistently linked to one or two of the matrix elements of the CoRe to help connect the observed practice with the account written by the teacher on that particular content.

The goal of each PaP-eR is to display interactive elements of teacher' s PCK, in ways that are meaningful and accessible to the reader and which may serve to encourage the reflection on PCK and open to the possibility that the reader modify his/her own practice.

CoRes were built from a small group of teachers and are limited in that they do not enable us to "to see" a whole education in action, or to tell us how teacher's beliefs about the represented knowledge influences their practice, but gathered with the PaP-eRs could serve to reveal the basic knowledge of the teacher and even act as a trigger that can help other teachers (both pre and in service) to reflect on their practice and develop their own PCK.

Triangulation done

PCK information obtained of ten high school teachers in Mexico were "triangle" with:

1) The corresponding analysis of alternative conceptions and learning difficulties of a sample of 388 Mexican students of the baccalaureate level, subject to two diagnostic tests on the topic;
2) The analysis of the content on acids and bases chapter of eight textbooks frequently used in secondary chemistry schools in Mexico;
3) The revision of the curriculum of middle and high school chemistry in which the subject acidity and basicity is taught;
4) The alternative conceptions and learning difficulties reported in the literature on teaching and learning the subject, university and school level chemistry textbooks in their acid-base chapters.

Methodology

We describe the procedure to capture and analyze of Mexican teachers' PCK on Acidity and Basicity at high school level, developed between 2007 and 2011. We documented the CoRe of the ten teachers and the PaP-eR of one of them, with another teacher in training.

A. Capturing and documenting Content Representation (CoRe).

The CoRe was documented by the questionnaire proposed by Loughran *et al* (2004), the original one is included in Table1, and it was subsequently modified by us. These authors (2006, p. 23) express that any section of a questionnaire CoRe can have more detail than the other, due to the form of representation of the CoRe, so it "allows to make changes and/or additions as the understanding broadens or as other issues are clarified and refined". That is the reason why we dare to make some changes in the questionnaire.

1. What do you intend the students to learn about this idea?
2. Why it is important for students to know this?
3. What else do you know about this idea? (That you do not intend students to know yet).
4. Difficulties/limitations connected with teaching this idea.
5. Knowledge about students' thinking, which influences your teaching of this idea.
6. Other factors that influence the teaching of this idea.
7. Teaching procedures (and particular reasons for using these to engage with this idea).
8. Specific ways for ascertaining students' understanding or confusion around this idea. (Include probable range of responses).

Table 1. Original CoRe questionnaire from Loughran *et al*, 2004.

• Pilot study.

The original questionnaire of Loughran *et al* (2004) was presented to 64 high school teachers, who formed teams of 3-4 members, developing a topic of their choice, in the workshop "Pedagogical content knowledge in chemistry: Something that good teachers possess", presented at a university in Mexico City (Universidad Autónoma de la Ciudad de México), on December 2007, under Internet supervision (on March 2008) until the delivery of their answers, fifteen days later.

On analyzing the responses, it was considered appropriate to make some changes:

1) The purpose of the questionnaire was mentioned subsequently and it was requested to quote three to five "Central Concepts" of the theme chosen. The term "central concepts" was mentioned with the following meaning "those concepts that are at the core of understanding and teaching the topic; they are those that belong to the disciplinary knowledge which you usually use to split the topic. The clue is that those concepts sharply reflect the most important of the theme, even including some of its precedents".
2) To reduce to one the first two questions of Loughran *et al.*: "What do you intend the students to learn about this concept and why is it important for students to learn it?"
3) To join in one the questions 4th and 5th: "What are the difficulties connected to the teaching and learning of this concept?"
4) To create new questions instead of Loughran *et al.*'s 3rd and 6th (see Table 1):
    a. What content and skills students should have as background just entering the school to properly understand the concept?
    b. What knowledge about the conceptual, procedural and attitudinal activities of students influence your teaching of this concept?
    c. What knowledge you know about history, epistemology and philosophy of this concept? And what historical aspects are important for teaching it?
    d. In particular, what aspects of daily life are important in teaching this concept?

With the modified questionnaire, the four hours workshop: "Pedagogical Content Knowledge. A reflection to the task of teaching" was directed by one of the authors

(Alvarado) in a meeting organized by the Mexican Academy of Teachers of Natural Sciences of Mexico on November 2009, with the participation of 23 teachers from middle and high school chemistry. The teachers formed teams of 3-4 members and developed a topic of their choice, which could be different from acidity and basicity, but preferably not. From the responses of teachers and further discussion it was concluded that the questions were clear and understandable.

• Final study.

During the second half of 2009 it was considered advisable to contact teachers with experience in teaching the subject in high school or fresh undergraduate. Ten of them, with extensive experience in teaching the subject, availability and positive attitude towards collaboration, joined the project. They were informed that they would receive e-mail with the data capture format to document the concepts considered fundamental for lecturing the subject (Table 2). This required to reflect on their beliefs, knowledge, skills and abilities, activities, examples, demonstrations, problems, etc. that, in their experience, had been helpful to them to teach the subject. In order to answer the questionnaire, they should write first the concepts they considered central to the subject; and then writing on their teaching objectives; knowledge of alternative conceptions learning difficulties of students; the appropriate sequencing of topics; the correct use of analogies and examples; ways to address the central concepts through experiments, projects, problems, essays or controversies; and ingenious ways of evaluating student progress and understanding.

<table>
<tr><td colspan="2">PEDAGOGICAL KNOWLEDGE OF EXPERT TEACHERS IN THE SUBJECT OF "ACIDITY AND BASICITY" AT HIGH SCHOOL LEVEL.
This questionnaire has been designed with the purpose of documenting the knowledge that teachers have experienced on the subject of "Acidity and Basicity" guiding students to understand the subject in a way personally meaningful to them. The information you provide will help us to implement the Teaching-Learning Sequences that contribute to the training and retraining of teachers of high school in the area, enriching the delivery of content in the classroom and avoiding, in many cases, the monotony of the lectures. We sincerely appreciate your cooperation.</td></tr>
<tr><td>Name</td><td></td></tr>
<tr><td>Age</td><td></td></tr>
<tr><td>Academic degree</td><td></td></tr>
<tr><td>Level at which you lecture</td><td></td></tr>
<tr><td>Global Teaching Experience (years)</td><td></td></tr>
<tr><td>Teaching experience in the subject of Acidity and Basicity</td><td></td></tr>
<tr><td>i. How relevant is the topic of acidity and basicity in a high school course?</td><td></td></tr>
<tr><td>ii. What content and skills students should have before entering the school to understand the issue</td><td></td></tr>
</table>

properly?					
Place in the three to five rows on the right the name of the central concepts (CC) on the topic of "Acidity and Basicity". We understand by those central concepts in the "core" of understanding and teaching the subject, are the most important concepts that are part of disciplinary knowledge in which you divide or split the teaching of the subject, including perhaps some of its precedents. Please answer as widely as possible, for each of the core concepts (CC), the following questions:					
	CC1	CC2	CC3	CC4	CC5
1. What do you intend the students to learn about this concept and why is it important for students to learn it?					
2. What content and skills students should have as background just entering the school to properly understand the concept?					
3. What knowledge you know about history, epistemology and philosophy of this concept? And what historical aspects are important for teaching it?					
4. In particular, what aspects of daily life are important in teaching this concept?					
5. What are the difficulties connected to the teaching and learning of this concept?					
6. What knowledge about the conceptual, procedural and attitudinal activities of students influence your teaching of this concept?					
7. What procedures and resources (analogies, metaphors, examples, videos, demonstrations, simulations, practical activities, etc.) are used for students to motivate and be committed to the concept?					
8. What specific forms used to assess understanding or confusion from students about the concept?					
iii. Comments and/or contributions to the teaching/learning of the subject and the central concepts mentioned by you.					

Table 2. Questionnaire to capture the PCK of Mexican teachers (modified from Loughran *et al*, 2004).

In order for teachers to reflect on their answers, they were asked to forward them in three to four weeks. They had the prerogative to change them as they wished, as long as they resorted to their own knowledge, beliefs, opinions, etc.., preferably without consulting books, articles, etc.

All teachers were linked to UNAM, either as students or teachers in service, whether at the School of Chemistry, or the high school at UNAM: National Preparatory School (ENP is the acronym in Spanish) or the College of Sciences and Humanities (CCH Spanish acronym) or either of other school (two of them are working now at a private school and a third at the University of Arizona, USA).

• Analysis of information.

During the first half of 2010, as questionnaires were received back, we proceeded to analyze them. Initially we reviewed the responses of individual teachers, to get an idea of the type answers of each of them. The purpose of the project was considered to obtain the knowledge, strategies, skills, attitudes, etc., instead of the educational profile of teachers, because we were involved in the design and development of the TLS to support the teaching and learning of acidity and basicity, in high school, as was mentioned.

Subsequently the responses of all teachers at each of the survey questions were transcribed. But the main objective was first to know which central concepts the teachers cited and which of them were cited more often.

Then we proceeded to concentrate information of the nine central concepts cited at least twice, but we noted that some of them were closely linked to each other; we proceeded to regroup them and reduce to eight, which were considered definitive for the analysis and reporting of the information captured. Those eight central concepts will be referred as consensual in what follows. In some cases they were not considered central concepts initially, as in the case of Neutralization/neutralization reaction, to which was added the titration feasibility. Commentaries written by the ten teachers regarding the eight consensual central concepts were incorporated, even though not all of them were cited as such.

Table 3 presents the total central concepts cited by teachers.

Teachers	Central Concepts	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
6	pH	X	X			X		X		X	X
4	Concentration	X	X	X					X		
3	Neutralization / neutralization reaction					X			X	X	
3	Relative strength of acids and bases	X		X			X				
3	Defining acids and bases as Brønsted-Lowry model / acid-base reaction in aqueous dissociation as particle exchange H +	X					X	X			
2	Acids and bases in terms of Arrhenius		X					X			
2	Water auto-ionization (and pH)			X						X	
2	Concept of acids and bases									X	X
2*	Acid-base equilibrium/Acidity constant										XX
1	Nomenclature of inorganic compounds	X									
1	Substance		X								
1	Amount of substance		X								
1	Electrolytic dissociation			X							
1	Polarity bond			X							
1	Water and composition				X						
1	Acids and bases as opposite and				X						

	complementary										
1	Daily water as a solvent and food conveyor				X						
1	The electrolytes and ions				X						
1	Compound					X					
1	Molecule					X					
1	Ion					X					
1	Quantitativeness of acid-base reactions						X				
1	Ampholytes and dismutation						X				
1	Feasibility titration						X				
1	Acid-base indicators							X			
1	Acids and bases. Lewis model							X			
1	Distinctive Properties of substances								X		
1	Reactivity								X		

* Cited twice by the same teacher. Considering its importance to the topic acidity and basicity, it was considered appropriate to include it as one of the consensual concepts.

Table 3. Full set of central concepts quoted by the ten Mexican teachers.

After regrouping, Table 4 presents the eight key concepts of the topic of acidity and basicity, considered definitive and consensual for the development of the CoRe documentation.

Teachers	Central Concepts	T1	T2	T3	T4	T5	T6	T7	T8	T9	T 10
8	pH/relative strength of acids and bases	X	X	X		X	X	X		X	X
5	Concept of acids and bases/Distinctive Properties of substances/substance/Reactivity		X		X				X	X	X
4	Neutralization/neutralization reaction/Feasibility titration					X	X		X	X	
4	Concentration	X	X	X					X		
3	Define acids and bases according to the Bronsted-Lowry model/acid-base reaction in aqueous dissociation as particle exchange H^+	X					X	X			
2	Acids and bases in terms of Arrhenius		X					X			
2	Water auto-ionization (and pH)			X						X	
1	Acid-base equilibrium/Constant of acidity										X

Table 4. Consensual Central Concepts most often mentioned by the ten teachers.

The phenomena and processes involving acidic and basic solutions offer an excellent opportunity for the teacher to help students develop conceptual, procedural and attitudinal activities, required for the proper understanding of the subject. So it was decided to consider those three different kinds of contents in the analysis of the answers of the ten teachers in relation to the eight central consensual concepts. Then, classifying the comment of teachers regarding the categorization within the scheme of Table 5 was performed the analysis of the responses to each of them.

1. CONCEPTUAL CONTENT. 1.1 Historical aspects 1.2 Importance of learning. 1.3 Relationship with the daily environment. 1.4 Knowledge and skills required for learning history. 1.5 Difficulties in the teaching-learning process. 1.6 Procedures and resources to motivate students. 1.7 Evaluation.
2. PROCEDURAL CONTENT 2.1 Logical skills. 2.2 Math skills. 2.3 Experimental Skills. 2.4 Communication and outreach skills
3. ATTITUDINAL CONTENT 3.1 Related to teachers. 3.2 With regard to students.

Table 5. Structure of the documentation of the Content Representation of "Acidity and Basicity" of ten Mexican teachers.

An approach to teaching profile of each of the teachers was also developed and it will be presented in table 6 below.

B. The capture and documentation of the Pedagogical and Professional experience Repertoire (PaP-eR).

To complement the documentation of the PCK as Loughran *et al* (2004) recommend it was documented a PaP-eR, through non-participant observation in a high school classroom during the development of the "Acidity and Basicity" topic, by one of the in-service teachers surveyed (T2).

The teacher was asked to allow videotaping the sessions of the course, which was taught by her and a female teacher in training. The in-service teacher had participated in various educational projects and is highly regarded by professors of the School of Chemistry and students on campus who she teaches. She is recognized as a professional, accessible and flexible, open to change, with high spirit partnership and has developed in practice team work without any trouble.

The teacher commented that in the course of the sessions, a teacher in training would do her supervised teaching practices -compulsory within the curriculum framework of the Master of Teaching for Higher Secondary Education, Chemistry option, commanded by the School of Chemistry of the University- so that both teachers planned and developed a teaching unit on the subject.

The sessions were conducted in the normal course in the classroom-laboratory students attending class as usual (see Figure 3), in the Science and Humanities High School "College" -South Campus (CCH-S is its Spanish acronym) of UNAM.

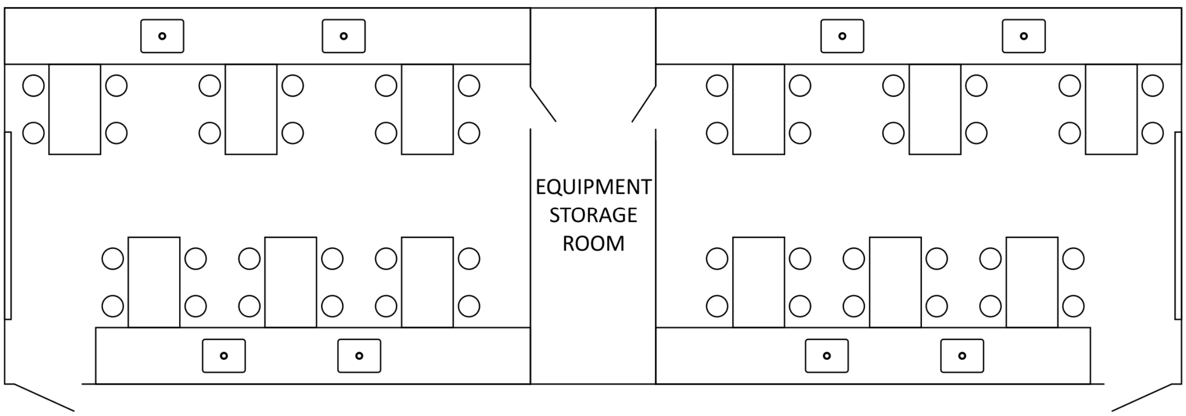


Figure 3. Duplex classroom-laboratory with storage room in the middle.

Both teachers dedicated seven sessions of between 90 to 120 minutes each to develop the subject 'Acids and Bases' of the unit: "Soil, nutrient source for plants", of the course Chemistry II, in the second semester. An author of this paper (Alvarado) recorded six sessions for two consecutive weeks. The actual time spent on the topic, was eight hours thirty-six minutes, of which six hours and forty minutes were videotaped (one recording of an experimental session was missed, but the next session of the corresponding discussion was indeed recorded).

It was considered essential that the observation was non-participant to avoid interference that could affect the development of classroom sessions.

The technique of registering data and observational instruments was conducted by the system of categorization (the subtopics treated, interventions by teachers and students, etc.), as framework to recover the most important aspects of the class.

Furthermore, we intended to recover the anecdotic record of conceptual, procedural and attitudinal aspects, manifested by both teachers, the first in service (Ts) and the second in training (Tt). It was considered that the interaction between them and the students were very interesting and not often it was recorded. Usually between 26 and 30 students attended per session (16-18 years old), which were informed about the purpose of the observation and that the sessions would be recorded on video, not expressing any qualms about it.

A verbatim transcription of all recorded material in video was made. Some minor adjustments were made in the order of the material to organize the six observed sessions in which the topic of acidity and basicity was given and gather all the content of each of the subthemes. The transcribed document was enriched with captured images of the video, or drawings that favored the understanding of what was expressed or desirable to enrich the information of the PaP-eR.

The analysis of the observation was based on the categories corresponding to the nine main sub-themes that had been addressed during the development of the sessions. A description of each of them and a discussion of the most relevant -considering the main central ideas that were described in the two teachers' CoRes and the alternative conceptions of students- are mentioned below in the "Results and Discussion" section.

C. Results and Discussion.

This section presents the results and analysis of the information of Pedagogical Knowledge of acidity and basicity, in the high school level.

• Documentation of the CoRes.

The teachers, all in the field of chemistry, (seven women and three men) will be indicated in what follows as T1, T2, … T10. The age of them ranges between 34 and 73 years old. Four have a bachelor degree in various fields of chemistry, three Masters in Chemistry and three PhD in the same area. Moreover, one of them had the degree of Doctor of Pedagogy and three were Pedagogy Masters. His overall teaching experience ranged between 8 and 39 years teaching experience and in the subject of acidity and basicity between 5 and 39 years. At the end of this section a résumé of the characteristics of the answers given by the ten teachers will be presented, but by now we restrict to the general ones cited in table 6.

Professor	Age (years)	Academic degree	Level taught courses	**Teaching experience (years)**	**Teaching experience in Acidity and Basicity (years)**
T1	40	Degree in Chemistry and Master of Education.	High school	13	5

T2	43	Doctorate in Chemistry	High school Undergraduate	23	23
T3	46	MSc in Chemistry	Secondary High school	20	20
T4	73	MSc in Chemistry	High school Undergraduate	39	39
T5	64	MSc in Chemistry	High school	35	35
T6	63	Ph.D. in Analytical Chemistry	High school Undergraduate Master	34	34
T7	38	BS in Chemical Engineering and Master of Education.	High school	8	8
T8	45	Doctorate in Chemistry	High school Undergraduate	22	22
T9	34	BS in Chemical Engineering and PhD in Education	High school	9	9
T10	47	Degree in Chemistry and Master of Education	High school	20	20

Table 6. Overview of the ten Mexicans teachers surveyed.

The eight teachers, highlighting its connection to everyday life, considered the acidity and basicity theme very important. This was expressed by some of them as follows:

> *It is relevant because these terms are used on a daily basis. That is, all students have some knowledge, right or wrong, on the topic*[T2].

> *It is important that students know that acids and bases are among the most common substances in nature and recognize the importance of pH in chemical reactions, including those that take place daily*[T5].

When questioning about what content and skills students should have entering the school to properly understand the issue, the responses of the teachers have a noticeable dispersion, focusing mainly on disciplinary content: Chemical Reactions[T1, T6, T8, T9] and Concentración[T2, T3, t6, T10], four times each. One comment about chemical reactions was: "Possess knowledge of common chemicals, acids, bases, salts and organic compounds, their properties and how they react"[T6]; a teacher [T8], with respect to concentration, said: "The concept of concentration and its application to the preparation of solutions, including when making dilutions". Three times cited: Chemical bond[T1, T3, T6], Stoichiometry[T3, T6, T10], Logarithms[T2, T6, T7], Structure and Properties of matter[T1, T4, T8] and Chemical Nomenclature[T1, T3, T6].

Among the skills required to cover the topic, stood out:

Thinking skills for management of mathematics and development of formal thought[T1].

The student should have acquired the skills of comprehensive reading and ability to express themselves verbally and in writing, with clarity, precision and conciseness. In addition, knowing why chemical reactions occur and having developed observation skills in the laboratory must motivate the student[T6].

Figure 4 shows that, over the eight surveyed questions of CoRe related to the central concepts that each teacher selected (Table 3), the three questions that involved more extensive responses were: No.1, regarding the importance of learning, No. 2 with respect to the background content and skills students must possess to properly understand each concept, and No. 6, on the conceptual, procedural and attitudinal learning that influence each of the concepts. The three questions that fewer words were used: No.8 related to specific forms of assessment, No. 4 on its relationship with the daily environment, and No. 5 with respect to the difficulties connected to teaching and learning each of the selected concepts.

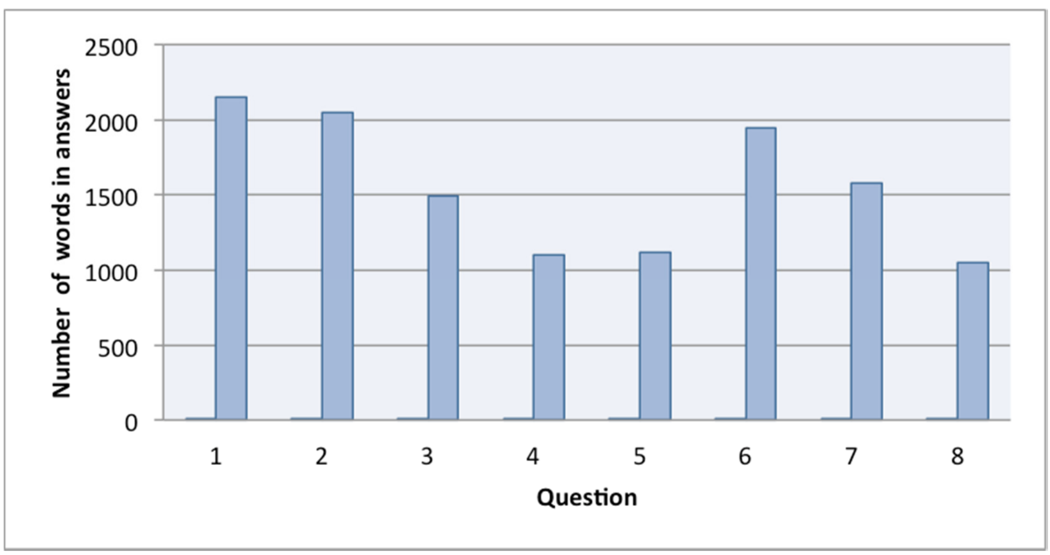


Figure 4. Total number of words in teachers answers to each question.

In order to get an idea about the knowledge and interest of teachers surveyed on conceptual, procedural and affective aspects of the teaching-learning process of the subject, we determined the number of words used for each of them: the approximately 17,000 words in total ten teachers employed, 66.0% were in the conceptual aspect, the procedural 24.6% and 9.3% to affective (in this case, both reflections of teachers on their own teaching as regarding their students).

Integrating documentation CoRe of "Acidity and Basicity" of ten Mexican teachers, regarding final eight core concepts is carried out using the structure described in Table 5. Below are quotations from some of the teachers, as examples for the central concept *pH/Strength on acids and bases.*

1. CONCEPTUAL CONTENTS.

1.1 Historical aspects.

In this portion of the paper the verbatim transcription of sentences mentioned in the CoRe by the ten teachers will be enhanced. At the end of the transcription, it will be used a superscript with the letter "T" followed by the number of the teacher.

> *The concepts used today are the result of a series of investigations of different people at different times and together make up part of the historic fabric that precedes countless concepts that we take as the latest and most relevant*[T1].

> *The background to the concept of strength is placed on the contributions in the eighteenth century by Bergman, who related the force with the amount of each reagent, and from Richard Kirwan, who related it with the rate of reaction between acids and bases*[T1].

With respect to the use of different models for considering acid and base behavior, our results show the same as the nine teachers studied by Drechsler and van Driel (2008): "although all teachers recognized some of the students' difficulties as confusion between models, only a few chose to emphasize the different models of acids and bases" (p. 611) and these authors also mention that the existence of those models give teachers a good opportunity to discuss the use of them to explain phenomena in a historical perspective (p. 612).

> *Arrhenius proposed in 1887 the concept of force as an absolute concept, while Brønsted and Lowry (1923) conceive it as a relative property* [T1].

It was scarcely mentioned the Lewis acid-base model by any of the teachers, where acids are defined as electron pair acceptors and bases as electron pair donators (Drechsler and Schmidt, 2005, p. 21). But these authors also mention "The Lewis model and other more advanced acid-base models are not taught in upper secondary schools" (p. 24), although it is contemplated in many of the high school Mexican curricula.

With respect to Sorensen, we had several teachers mentioning things like the following:

> *Consideration should be given to Sørensen (1909) on the concept of pH as a way to simplify the management of concentrations, as a new way to measure the acidity of sustances*[T6].

> *The implementation of the use of a logarithmic scale for pH, considerably facilitated handling the concentration values of hydronium or hydroxyl ions*[T6].

1.2 Importance of learning.

Many quotes appear with respect to the importance of learning pH concept, mainly due to the everyday use of it:

> *The concept of pH facilitates handling of the concept of acidity and basicity, parameter often used in daily context* [T1].

> *The pH allows the understanding of why two acidic or basic substances that are at the same concentration, have different degrees of acidity or basicity*[T1].

> *"pH" is one of the most famous terms of chemistry between students*[T2].

> *The concept of strength helps establish less empirical classifications of acids and bases and facilitates understanding the concept of pH*[T3].

> *The pH allows students to differentiate between chemical force of a material (measured as the degree of dissociation) and the chemical character of that material*[T7].

> *pH is useful to discuss the dissociation of water and determine the relationship between the concentrations of H_3O^+ and OH^- in aqueous solutions, which leads to the pH scale and determine the acidity or alkalinity of a disolución*[T10].

1.3 Relationship with the daily environment.

Science-Technology-Society dimension is fully considered by the almost the ten teachers surveyed:

It is important to assess the importance of pH control in the reactions that occur in living beings[T5].

In the everyday environment, the force can be related to the care that must be taken when handling strong acids or bases to prevent accidents that could be fatal: the reactions between acids and strong bases can be violent and release significant amounts of heat[T6].

It is important for students to recognize that there are different types of acids and bases, some are stronger than others, and that its effect depends on both its relative strength and its concentration in solution; they must understand that it is not the same, for example, to ingest sulfuric than ascorbic acid[T8]*. Changes of pH in water by pollutants should be controlled, as well as activities such as agriculture, medicine, cleaning, etcétera*[T9].

1.4 Knowledge and skills required for learning.

There are several concepts and skills cited by the teachers as necessary for learning the topic:

For a proper understanding of the concepts of pH and concentration, it is important the concept of amount of substance, as the student must understand that upon weighting one counts indirectly the number of chemical elementary entities of a substance[T2].

The concepts of dissociation of acids and bases, and auto-dissociation or auto-ionization of water should be clear, as well as the logarithm operation[T2].

The acids and bases definitions as given by Arrhenius are required as a historical reference, as well as the definition of pH of Sørensen[T6].

It is greatly facilitated when students are well prepared in the knowledge of the International System of Units (including the magnitudes of mass, amount of substance and temperature) solubility, solutions and dilutions, as well as about the particle nature of matter[T6].

1.5 Difficulties in the teaching-learning process.

The teachers recognize a lot of difficulties, mainly in the learning process:

> *There are numerous and diverse difficulties in the process of teaching and learning the concept of pH, for its complexity, so clearly there is no full differentiation between the terms acidity and pH*[T1].
>
> *Consider the idea that the strength of the substances is absolute and is not displayed as a relative property*[T1]
>
> *Because the difficulty explaining logarithmic variations, the students find difficult to relate the pH value with exponentially increasing amounts. They have poor management of exponentials, and are confused by the fact that the lower the negative exponent is the higher the ion concentration of* H^{+}[T2]
>
> *They generally think on a scale of a unique pH scale, and that neither the temperature nor the dissolvent have an influence*[T4].
>
> *Students used as synonymous strength and concentration, the strength of the acid must be related to the acidity constant and not considered as formerly*[T6].
>
> *They find difficult the identification of the different variables to be taken into account to predict the effects of a certain acid / base, usually make predictions based on a single variable and despise the other effect (only concentration and strength, or vice versa)*[T8].
>
> *Understanding the concept of pH and acidity is complicated because the pH varies inversely with the concentration of ions hidronium*[T9].
>
> *Students have an idea of what pH is, but the concept is not manageable by them, nor they can handle or interpret qualitatively or cuantitatively*[T10].

1.6 Procedures and resources to motivate students.

Surveyed teachers often refer to affective components of the teaching/learning process. As an example we selected these couple of verbatim expressions related with motivation:

To attract students to the concept of pH it is resorted to various procedures and resources, among which stand out experimental activities; classify everyday materials such as acids or bases according to their pH and contrast with its previous hypothesis; also recreational activities (games where simple calculations are made) and classroom experiences[T1].

Calculations are made to determine the pH; discuss the concepts of acid, base and pH that the student possesses; exercises are performed to represent microscopically a solution by adding an acid, in terms of training and concentration of H+; to develop work proposals by students for research; using films, models, demonstrations, computer animations and simulations [T9].

1.7 Assessment

The following are expressions concerning the evaluation of student's outcomes:

Class exercises are performed to calculate pH, and to evaluate the concentration concept learning; students are asked to imagine the molecules and ions that have been discussed in class, while having opposite them a prepared solution and make a drawing or sketch of that image[T2].

To design experiments to solve a problem, for example, to quantify the amount of acid present in a kitchen substance; to explain what happens to the concentration of H^+ *when adding a base or an acid to the solution. An individual written evaluation is made, where exercises are asked to be made in order to relate the ion concentration and pH. Posters are developed for research on applications or phenomena in which the pH is relevant (industrial, environmental, etc.)*[T9].

2. PROCEDURAL CONTENT.

There were a few of logical and experimental skills shown by the teachers as important for students to manage. There is an overemphasis on mathematical skills in this topic.

2.1 Logical Skills

Managing logarithmic functions such as calculating the expression for the pH of a solution, for the qualitative interpretation of the meaning of the numerical value and its implicacions[T5].

2.2 Math skills.

Drechsler and Schmidt (2005) also indicate that Swedish high school teachers faced problems with the lack of knowledge of their pupils on stoichiometric calculations, logarithms and buffer solutions.

Students refuse to use mathematical relationships to calculate pH and to understand its relationship with the concentration of H^+ ions, as well as handling very large quantities using exponents[T7].

Students do not know really what a logarithm is, they only know that in their calculator there is a key with the "log" name.[T5]

2.3 Experimental Skills

The preparation and management of acid-base indicators, potentiometer, etcetera is almost absent in students[T4].

2.4 Communication and popularization skills.

The use of new technologies for searching, capturing, recording and reporting data is overemphasized, for example, during experimental activities[T6].

3. ATTITUDINAL CONTENT.

3.1 With respect to the teacher.

It is considered a waste of time to have a group of students doing calculations of pH, while most of them do not have a clear understanding that it is being spoken of atoms and molecules to explain the properties of substances[T2].

3.2 With regard to students.

Favor the rote learning of the pH scale, without going into the mathematical expression of pH and its qualitative explanation[T10].

An overview of the teacher profile with respect to acidity and basicity of the ten of the teachers surveyed is shown in Figure 5 and Tables 7, 8 and 9.

It is worth mentioning that teachers T5 and T6 had virtually the same age (64 and 63, respectively) and had very similar years of experience in lecturing the subject Acidity and Basicity (35 and 34), however, are located at the ends as to the number of words used: T6, one of two teachers who elaborated more, and T5, which was more succinct (he even didn´t answer some of the questions). On the other hand, the two professors who used more words are located at the ends with respect to teaching experience (T1, a few years, and T6, a long teaching career). These data are presented solely for the purpose of having an insight into how much each teacher elaborated to answer the questionnaire, without this being an indication of the quality of it.

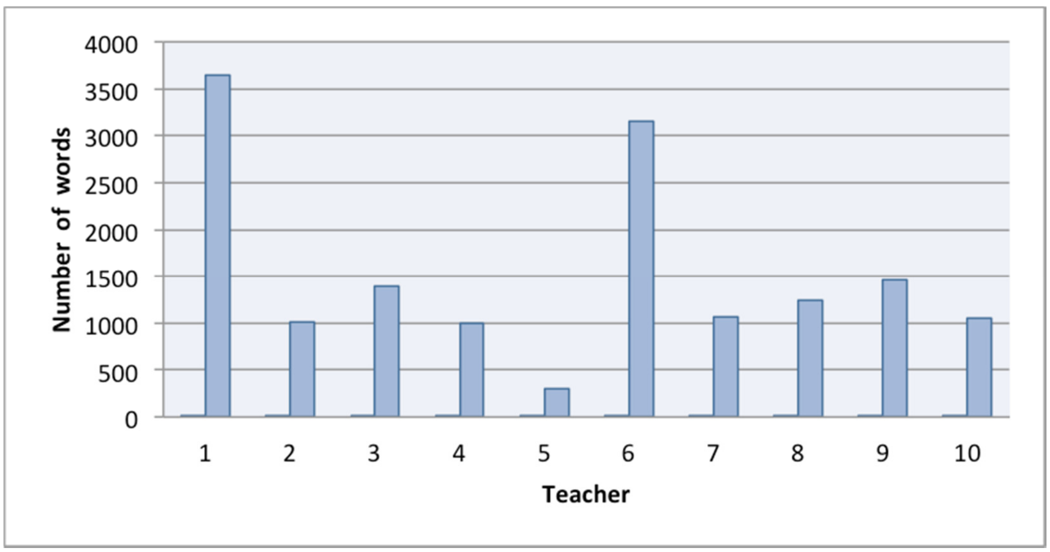


Figure 5. Total number of words in answers, by teacher

A table was developed for each selected central concept, which details the responses to the survey questions in which each teacher expressed any comment related to each of the indicators for the analysis of the conceptual, procedural and attitudinal contents. For example, Table 7 indicates that with respect to the central concept pH/relative strength of acids and bases, T1 referred to the historical aspects in his responses to questions 2, 3 and 4; T2 made no reference and T3 did it in questions 2 and 3.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
CONCEPTUAL CONTENTS										
Historical aspects	2-3-4		2-3			2-3	2		2	2-3
Importance of learning	1	1	1	6	1	i-ii-1-3-4	1	1-3	1	1
His connection with the daily environment	3-7		iii	6	3	3-7	ii	3-7	1-3-7-8	6-7
Knowledge and skills required for learning	ii-5	iii-1-4-5	ii-1-3-4-6			ii-1-4	1		1	1-3-4-6
Difficulties in the teaching-learning process	4-5	4-5-6	6		5	4-6	3-4-5	5	4-5-6	3-4-5
Procedures and resources to motivate students	3-7		7			7	7		7	3-7
Assessment	8	8	8			8			8	8
PROCEDURAL CONTENTS										
Logical skills	ii-4-5					ii	5			5
Math skills	ii-4-5	ii-4-5-8	ii			ii-8	ii-3-4	5	4-5-6	ii-4-5-6
Experimental skills	7-8		7-iii			ii-7			7	7-8
Communication and popularization skills	8		8		ii				8	ii
ATTITUDINAL CONTENTS										
With respect to the teachers	3-5								4	
With respect to the students	3-5		6-iii							4

Table 7. Questions/answers from the CoRes, categorized by the various indicators for the analysis of the analysis indicator items; the central concept was pH/relative strength of acids and bases. Inside the matrix elements the number of the question where the teacher responded on that item is presented.

Table 8 shows the number of the eight central concepts in which the teacher gave information regarding the conceptual, procedural and attitudinal items; thus, for example, T1 addressed historical aspects on six of the eight selected central concepts, T2 only to two and T3 to five.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
CONCEPTUAL CONTENTS										
Historical aspects	6	2	5	1	-	6	7	3	3	5
Importance of learning	4	4	6	2	4	7	4	4	5	4
His connection with the daily environment	4	2	3	2	3	2	5	4	3	3
Knowledge and skills required for learning	6	3	7	1	1	4	2	1	4	5
Difficulties in the teaching-learning process	5	4	4	2	3	6	4	4	6	3
Procedures and resources to motivate students	4	3	4	2	1	3	4	3	5	5
Assessment	4	3	4	-	2	5	1	3	4	3

PROCEDURAL CONTENTS										
Logical skills	4	1	-	-	-	1	3	3	1	1
Math skills	4	2	3	1	1	4	5	4	1	6
Experimental skills	4	1	4	1	-	6	2	3	2	3
Communication and popularization skills	4	1	4	-	1	4	2	3	2	5
ATTITTUDINAL CONTENTS										
With respect to the teachers	4	-	1	-	1	-	2	2	1	1
With respect to the students	4	-	5	-	-	3	-	2		2

Table 8. Concentrate of the reference of the ten teachers to the eight central concepts, regarding the analysis indicators selected.

Table 9 shows the abundance/importance of each teacher´s information expressed for each one of the conceptual, procedural and attitudinal items.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
CONCEPTUAL CONTENTS										
Historical aspects	Ab	S	R	R	Abs	R	R	R	R	R
Importance of learning	R	R	R	Ab	R	Ab	Ab	R	Ab	R
His connection with the daily environment	Ab	S	R	R	S	R	R	R	R	R
Knowledge and skills required for learning	R	S	R	S	S	Ab	S	S	R	R
Difficulties in the teaching-learning process	Ab	R	Ab	R	R	R	Ab	Ab	R	Ab
Procedures and resources to motivate students	R	R	S	R	S	R	Ab	R	Ab	R
Assessment	R	S	S	R	S	R	S	R	R	S
PROCEDURAL CONTENTS										
Logical, mathematics, experimental and communication / outreach skills	R	S	R	S	S	R	S	R	S	R
ATTITUDINAL CONTENTS										
With respect to teachers and students	Ab	Abs	S	Abs	S	S	S	S	S	S

Ab - Abundant R - Regular S- Scarce Abs - Absent

Table 9. Abundance/Importance of information expressed by each teacher about analysis indicators.

A brief academic résumé of each teacher is presented below taken in part from the information given above:

a) T1, a teacher 40 years old, with a Masters in the field of education, 13 years of teaching experience and five in the subject of acidity and basicity. Through her responses we perceived a high teacher's training and knowledge. Abounded on historical information, links to the everyday environment and difficulties in the teaching-learning process. She referred more often to attitudinal aspects. Supplied 100% of the information requested in the questionnaire, regarding the central concepts and was selected as the two teachers (He and T6) who were more extensive on the information provided.

b) T2, a teacher of 43 years old, with a Doctorate in Chemistry, 23 years of teaching experience, including the issue of acidity and basicity, very updated in teaching the subject, with a clear bias towards experimental activities. She is co-author of chemistry textbooks for secondary level. Provided interesting ideas, but in a very concrete way. Almost did not address the attitudinal content. Se answered about 72% of the information that was asked about the central core concepts that were chosen. This teacher served as teacher in the sessions that were videotaped in the classroom and she is now involved in the stage of action-research for the development of the TLS.

c) T3, 46 years old, with a Masters in Chemistry, 20 years of teaching experience in the subject. The aspect she extended more was on the difficulties of teaching and learning of the subject. She recognized not to know the term "epistemological" and did not deepen in the historical aspect.

d) T4, 73 years old, with a Master in Chemistry, 39 years of teaching experience, including the issue of acidity and basicity. She almost did not approach the attitudinal content. Only broadly addressed the importance of learning the subject. She only cited four central concepts and provided virtually no information regarding procedural and attitudinal contents. More attached to the disciplinary knowledge and she had no explicit answers. She delved into current pedagogical aspects, such as the importance of knowing the alternative conceptions of students.

e) T5, 64 years old, with a Masters in Chemistry, 35 years of teaching experience, including on the issue. Of the ten teachers, she provided the least information, and cited data only in the case of 44% of the central concepts, considering the selected analysis indicators. She gave very short answers and did not provide information regarding the historical, nor procedural and attitudinal contents. Also she was very attached to the disciplinary knowledge.

f) T6, professor 63 years old, with a Doctorate in Chemistry, 34 years of teaching experience in the subject of acidity and basicity. It is a well known professor as lecturer in teacher education programs. Although his responses involved both high school and undergraduate level, was one of the most widely extended teacher in regard to his responses, addressing the conceptual, procedural and attitudinal contents. Through his responses he showed a mastery of the subject, even if hardly addressed the difficulties of teaching and learning of the subject.

g) T7, 38 years old, with a Masters in Education, eight years of teaching experience, including the issue of acidity and basicity. Although he gave limited information about the issues that affect the teaching of the subject and of its assessment, he is a teacher with "fresh" ideas. This teacher worked in the stage of action-research for the development of the TLS.

h) T8, 45 years old, with a Doctorate in Chemistry, 22 years of teaching experience, and also on the issue. He is co-author of chemistry textbooks for secondary level and author of a large set of articles on the teaching and learning of chemistry. He provided information on all indicators of analysis of the central concepts that he chose. Even when he said that his knowledge on epistemology was very limited, he is a very innovative teacher.

i) T9, teacher 34 years old, with a Doctorate in Education, nine years of teaching experience, including the issue. Provided information on all indicators of analysis of the central concepts that she chose.

j) T10, 47 years old, with studies of Pedagogy, 20 years of teaching experience, including the issue of acidity and basicity. Provided information on almost all indicators of analysis of the central concepts that she chose, however, she recognized she should deepen on the historical evolution of the subject.

B. Pedagogical and Professional experience Repertoire (PaP-eR).

Each of the videotaped sessions is briefly described and we present some relevant comments on each one, based on the main ideas obtained from the analysis of teachers' CoRe, students´ alternative conceptions, and also some verbatim interventions by teachers (in italics), and students (in italics with a hyphen).

► During the first session, led primarily by the teacher in training (Tt), the subjects were: Why to study chemistry?; Acid-base duality; and the characteristics and properties of acids and bases at macroscopic and submicroscopic level. She spoke with students about studying chemistry and commented on natural processes involving physical, chemical and biological changes.

It was noted that on classifying, arbitrary criteria are established to form subsets, based on the lying interest that Chemistry has classifying substances.

> *These substances react with this, those not, they are burned, those not.*

It was indicated that the acid-base duality would be the scientific content of the following sessions and an article was read to help understanding the duality.

When asked about examples of acids, students cited examples as:

> *- citric acid, hydrochloric acid, sulfuric acid and aspirin, but also, gastric, lemon and urine.*

Then the teacher in service (Ts) said that the last three cited were mixtures containing respectively hydrochloric, citric and uric acids.

When a student cited as an example of a base the bicarbonate, Ts questioned the students how could be confirmed that it is a base.

> *- Because when you combine it with lemon ... tastes salty, then it is assumed that when you mix an acid with a base is a salt.*

> *- I dissolve it in water and measure the pH.*

It was left as homework the task of paying close attention in newspapers, television, Internet, etc., to identify information on acids and bases.

► Second session, driven mainly by the teacher Ts, is about the acidification of the oceans and the three levels at which it deals with the study of chemistry.

In talking about ocean acidification and its consequences, a student said:

> *- So in ten years it will no longer be so sure go into the sea?*

Tt said that it is not to be taken so seriously, but for marine environments very small pH variations of a few tenths of pH, could mean big changes, and that not all the seas and oceans were acidifying in the same ratio.

With respect to the three levels (Johnstone, 1993; Gilbert and Treagust, 2009) or viewpoints of chemistry (descriptive-macroscopic, submicroscopic and symbolic), Ts said that the three were equally important and that:

> *There is a reality of the world that it is really there, but it cannot be seen as such, and scientific knowledge is like another reality that is proposed and may or may not tie in with this, the interpretation we give the world is based on a number of theories, a series of knowledge.*

She said it would be interesting to talk about the reactions of acids and bases, in relation to a situation known as "heartburn". A task was to investigate the trade name, active ingredient, price, and presentation recommended dose (tablets, suspension, etc.) of the antacids.

At some moment it was asked to describe what happened at a submicroscopic level before and after a reaction between an acid and a base.

> *- They appear to be more aggressive.*
>
> *- They are more corrosive.*
>
> *- They react easier.*

When Ts asked about the tendency of bases to react when neutralized, they replied:

> *- So, I imagine they get tire to react and then they are neutralized.*
>
> *- In the base is quieter.*
>
> *- As they tend not to react.*

Ts said them that bases were so corrosive as some acids.

► The third session was devoted to modeling.

Tt presented three different maps of Mexico City: One of the stations of the Metro, another indicated streets, tourist attractions, ..., the third rail lines (Metro, so-called: Light train, and Electric train). She questioned the students about if one was better than the other two and on what basis.

- No, it depends of needs.

- From what you know.

She actually said *I could not say that one was better than another; it would depend on what they were needed for.* Then she asked: *What is a model?*

- It is how you imagine the things we cannot see.

- A graphic representation or scale of something that works well.

- As a point of view of someone, you imagine something and create a model in your mind.

Tt said that *the models were not necessarily representations of things we cannot see, could also be things we can see. A model atom of an atom was presented and said it was the representation of a complex idea and that a person who had not studied, hardly would apply the same meaning as us*. Then she questioned: *What criteria can guide the development of a map or a model?*

- The interest ... Needs ... Objectives ...

- The most important, most significant ...

- Who is it? Each model we use will have certain advantages and certain weaknesses, absolutely no one better than another.

Ts mentioned that *it is said that chemistry is a science of patterns that you cannot see and have to imagine what is inside*. She asked if *they had any useful study of various models*. Some students said:

- Yes, the models are modified according to what is being investigated.

- You cannot put to Young children in elementary school, a quantum model, they are just creating a conception of what the atom is. Go from basic to complex.

Tt explained that usually when one approaches a phenomenon one has an idea about it already, one has had certain models that help interpret the fact, and also during the work of scientists, other models are proposed and acted according them. The models are not definitive, they are not absolute truths, are propositions to be modified as needed, depending on what is being observed. A student expressed:

- The models are used as a theoretical framework. You cannot, for example, get to study the cell without having a theoretical framework prior to that, a theory, a model, and a proposal.

► The fourth session, led by Ts, was essentially about more properties of acids and bases, even at the microscopic level.

She asked: *If one imagines that on a small piece of metal, hydrochloric acid is added by dripping. What will happen?*

- I do not know, obviously it is going to be a reaction.

- May be it makes a hole ... I do not know.

- Bubbles come out.

Ts asked about what would those bubbles are:

- Hydrogen.

Ts confirmed: *It is right, the substance is hydrogen.*

Ts said that when it was said hydrochloric acid, every one thinks about a liquid, but ... *Is not a liquid.*

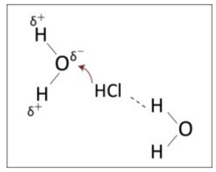
It was clarified that a gas could be called hydrogen chloride, and she questioned*: Why we always imagine it as a liquid?*

- Because it is dissolved in water.

Ts asked why the hydrochloric acid when drip in water, "it breaks":

- Oxygen attracts hydrogen and hydrochloric acid destroys the bonding.

After several clarifications on the board came to the following representation:



And Ts said that water had an "evil behavior", broke the molecules of HCl and separate them, but the water molecule remained intact and so "was born" an acid.

► The fifth session focused on the history of acids and bases, as well as heartburn, gastritis and antacids.

When Tt asked about which models were proposed to explain the properties and reactions of acids and bases and how it would be searched on the Internet, she indicated that a simple strategy for searching the Internet was writing keywords, eg. Acids history models bases.

Initially she said that the first known acids were some with we are in daily contact, such as vinegar. In the end, there was a talk about the Arrhenius model and other models to explain how acids and bases react.

Ts concluded the class by saying *"The substances dissolved in water that release hydrogen ions will be called acids: substances that in water donate hydroxil ions, we call them bases. They react with each other to form water and salts ... However, there are other acids and bases that do not fit this description. Let's say, that would be like the summary of this model, you do not need much more"*.

In addressing the issue of heartburn, Ts asked about what kind of antacids were and how they acted. A student said:

> *- Antacids are of two types: non-systemic (react with stomach hydrochloric acid forming a salt which is not absorbed, in a slow and prolonged action; there are salts of magnesium, calcium and aluminum) and systemic (react with hydrochloric acid in the stomach, a portion of the salt is absorbed in the stomach wall, in a potent and rapid action, but with transient effects produced by magnesium hydroxide and sodium bicarbonate).*

Then, completed a table, on the blackboard, with the more common antacids in Mexico, with the information that the students were providing on its main substances contained and its presentation.

► During the sixth session continued the theme of heartburn and it was treated the Arrhenius model of acids and bases.

This session began with a discussion of a laboratory activity performed in groups, to measure the pH of solutions of various commercial antacids, its reaction with hydrochloric acid, to determine what was the best.

Tt asked *what factors might influence thinking what was the best antacid*.

- *The amount that has been added.*

- *The one that better neutralizes the acid decreases the acidity with the least quantity.*

Tt said the criteria would be: "*One who with less quantity happens to neutralize more acid, will be the best*".

It was mentioned that several of the antacids are or contain hydroxides, but others were carbonates. Tt wondered if anyone remembered who proposed this model to explain that they were neutralized.

- *Arrhenius!*

Tt asked *someone found something about him?*

- *He is the one of the dissociation.*

- *No, ionization.*

Tt mentioned that the Arrhenius model explained very well the behavior of hydroxides and acids, and related properties, could explain the pH, was the simplest model, one the first ones. And explained a lot of things, but *there are many models of acids and bases*.

Subsequently, she spoke with respect to a reading, which deals with the causes of heartburn and HCl two main functions: The decomposition of food and attack to antibacterial proteins.

Regarding this she asked about what the role of hydrochloric acid in our body is.

- Unmake food.

- Protecting it from any food that is infected or something like this, you will damage the stomach because it breaks.

Conclusion

As a closing remark we are copying two questions that Abell (2008, p. 1412) posed to PCK researchers as future challenges: The first one is: "What is the relation of PCK (in terms of quality and quantity) to teacher practice?" The corollary question is: "What is the relation of PCK to student learning?" The last question was also mentioned as a next ten years interest of PCK researchers in the "PCK Summit" that took place in Colorado Springs, Colorado USA last October 2012 (The four talks in this symposium are presented by attendants to this meeting). We conclude that the next step to be taken is to evidence that PCK influence students' outcomes. As, Kind (2009, p. 198) emphasizes, "There is strong evidence that PCK is a useful concept and tool for describing and contributing to our understanding of teachers' professional practices".

Also in a recent work, Bertram and Loughran (2012) pointed out that PCK has been a researchers' attractive construct but "remained closeted in the world of academia" (p. 1027). Now they has shown that the two Loughran et al. (2004)'s instruments, CoRe and PaP-eRs are a meaningful methodology for teachers to examine their PCK progress:

> …gave [teachers] a stronger feel for their own professional development … and [enabled them] to explore in more detail the underpinnings of their teaching (p. 1030).

So a foreseeable conclusion is that PCK portraying must be used to evidence the kind of student outcomes when a given teacher with a given CoRe and PaP-eR takes action in the classroom, and as a teachers' training tool as a methodology for assessing the progress of PCK of teachers in formation and actualization.

We conclude this paper by writing a set of final paragraphs on the portraying of the CoRes of ten experienced teachers, and the PaP-eR taken to an in-service teacher and a teacher training while developing the action with a group of students.

A. Considerations for the CoRes.

The teachers' CoRes were used to determine the eight central concepts (Table 4) that are definitely important to address during the design and development of TLS.

It is remarkable the diversity of central concepts (28) mentioned by teachers considering that they all had the same experience in the subject, in the high school level, and all were linked in some way with the National University of Mexico. Later it was found that although they had not cited some of the eight aforementioned final core concepts as such, they referred throughout to them.

In relation to the teaching and learning difficulties on the subject, teachers cited only few students' alternative conceptions.

From the analysis of the responses of the ten teachers becomes valid the comment of one of the authors of this Proceedings (Mellado) about the big difference between an expert and an experienced teacher in a particular subject, since both terms are often considered synonymous. This large difference can be seen, for example, between the teachers T5 and T6: both of similar age and teaching experience, however, with a very contrasting expertise to address the issue.

Regarding the possibility of being able to differentiate from their responses, those who have participated in graduate studies in Pedagogy (as they are called in Mexico) or Didactics (as they are known in Spain), it becomes a complicated issue to make a very strict distinction as such; for example, both teachers T7 and T8, showed innovative ideas and possess good command of the topic, however, the first onewas studying a Masters in the field of Education at the time when asking to answer the questionnaire, while the second has not formal studies in this area.

B. Considerations about the PaP-eR.

An important conclusion reached after attending these sessions, was that it was necessary to strengthen the teaching and learning of acidity and basicity at the macroscopic level, as a result of a poor knowledge about this subject that was perceived among students.

On the topic related to acidity and basicity corresponding to the whole course of Chemistry II, its boarding during the sessions observed was adequate in general.

It was evident that teachers generally promoted students:

- Increase skills in finding relevant information for analysis and synthesis.
- Enlarge oral communication skills to express their views, basing its findings and conclusions.
- Recognition of experiments as an activity in which they control the variables involved in the process under study and as a way for obtaining information.
- Increase observation skills and handling equipment to experiment.
- Define Arrhenius' acids and bases properly.

However, it was not specially promoted students to:

- Describe some methods for obtaining salts in the laboratory.
- Express greater capacity for analyzing and synthesizing information obtained by experimenting.
- Increase their ability to formulate hypotheses.

Other conclusive remarks on the PaP-eR were the following:

- Very good behavior of teacher in training, extremely complete and related with several aspects of the context; no matter the little experience she had on teaching.
- The sessions took place in an atmosphere of trust, led by the friendly attitude of both teachers, who encouraged students to express themselves freely even though, except for rare exceptions, very briefly.
- Usually one of the teachers had charge of the session, even the other stepped making comments or clarifications or asking the students.
- It must be stressed that the sessions on aspects related with the submicroscopic level were driven primarily by the teacher in service, as the development of nanoscopic characteristics and properties of acids and bases, explaining reactions of acids with metals, and the role of water and its interaction with hydrochloric acid.
- It was given great importance to the Science-Technology-Society dimension, i.e. to the linkages between the topic and everyday life examples by discussing the properties and characteristics of acids and bases, obviously addressing modeling and especially to speak at length on the issue of heartburn, gastritis and antacids.
- It is considered important for this study to note that the teacher in service said in one of his comments and subsequent interview that she and the teacher in training had been

talking too much, they should promote greater participation and discussion by their students.

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