exciting opportunities here and it is not as difficult as might be first thought. The paper laboratory concept (see Shah, 2004) offers one way forward. Students seem to want more scope for freedom. With some thought, this is not too difficult to develop.

The third recommendation relates to laboratory organization. If the teachers and the students are sharing a common set of aims, then it is easier for the labs to be organized meaningfully. This need not involve large amounts of new chemicals or equipment. It does mean sitting down and planning to see how the agreed aims can be achieved effectively and efficiently. The criticisms of organization may not, of course, be reflected in all countries and all contexts.

The fourth recommendation considers laboratory reports and assessment. Both must reflect the agreed aims. Neither must distort the aims or emphasize things which are not important. For example, if an experiment seeks to illustrate the behaviour of some chemicals, then the report must offer an account of this and assessment must reflect the extent to which the student has grasped the chemical behaviour. On the other hand, if an experiment aims to allow students to plan an experimental enquiry for a stated purpose, then the assessment must show the extent to which the student has been successful in planning. The idea of allocating a mark many be meaningless. It may be much better to record that the student has carried out the task satisfactorily and achieved the aim set, the evidence of this being based on qualitative measures. Students want assessment; it is the task of the teacher to ensure that assessment is valid and helpful.

Finally, there are numerous important skills which can be developed by means of laboratory work: team working, observation skills, deduction skills, skills of analysis, evaluation and synthesis, skills relate to data handling, and so on. These can be part of a laboratory report and can also be assessed. In the long run, such skills may be *much more* important than correctly following laboratory instructions and getting a 'right' answer. Students clearly have difficulties with regard to the place and nature of reports.

The potential for laboratory work is simply enormous. It need not cost more in terms of time or money to achieve exciting outcomes. It does need clear thought, specification of aims, and a careful use of all aspects of assessment. Together, these can offer the next generation of students a much more enriching experience.

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Latin-American teachers' pedagogical content knowledge of the particulate nature of matter

Conocimiento pedagógico de profesores latinoamericanos sobre la naturaleza corpuscular de la materia

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Abstract

A documentation of 16 Mexican and Argentinean teachers' pedagogical content knowledge (PCK) concerning the teaching of the particulate nature of matter has been developed, following Loughran et al's methodology of Content Representations (CoRe) and Pedagogical and Professional experience Repertoires (PaP-eRs). A comparison is made between our three groups of teachers' answers of the central ideas related to the teaching of the topic with a previously informed one made by Australian teachers. A consensus version of the central ideas of Latin-American teachers was reached afterwards, which has five central ideas coincident with the Australians. A section is dedicated to compare our three groups of teachers' answers of the Content Representation questionnaire. A final short section is dedicated to explain the PaP-ers developed by three of our teachers, one of each one of our groups. These PaP-ers are offered on request by e-mail to the interested reader.

Key words: *pedagogical knowledge, content representation, particulate structure of matter, Latin-American teachers*

Resumen

Se ha desarrollado la documentación del conocimiento pedagógico del contenido (CPC) de 16 profesores de bachillerato mexicanos y argentinos, siguiendo la metodología de Loughran et al. de la Representación del Contenido (ReCo) y los Repertorios de Experiencia Pedagógica y Profesional (REPyP). Se lleva a cabo una comparación entre las ideas centrales respondidas por nuestros tres grupos de profesores y aquellas *informadas por un conjunto de profesores australianos. Posteriormente se alcanza una versión de consenso de las ideas centrales de los tres grupos de profesores latinoamericanos. Se dedica una sección a comparar las respuestas al cuestionario de la ReCo de los tres grupos y en una sección final se explica la naturaleza de los tres REPyPs desarrollados por tres profesores, uno de cada grupo. Se ofrece enviar por correo electrónico estos REPyPs a solicitud del lector interesado.*

Palabras clave: *conocimiento pedagógico del contenido, representación del contenido, estructura corpuscular de la materia, profesores latinoamericanos*

INTRODUCTION

SHULMAN (1986, pp. 8-9; 1987, p. 8) coined the term "teacher's knowledge base" as the "categories of knowledge that underlie the teacher understanding needed to promote comprehension among students". And inside it, the "pedagogical content knowledge" (PCK) as a specific category of knowledge, "which goes beyond knowledge of subject matter *per se* to the dimension of subject matter knowledge *for teaching*". Teachers do not only have to know and understand the subject matter knowledge (SMK), but they also must know how to teach that specific content effectively. It is therefore necessary to document science teachers' PCK in an increasing number of topics (DE JONG, VEAL & VAN DRIEL, 2002).

Several studies have indicated that PCK is acquired mainly by experience while teaching (GESS-NEWSOME & LEDERMAN, 1999). The results on PCK developed by student teachers in "learning from teaching" activities have been recently pointed out (DE JONG & VAN DRIEL, 2004), particularly those referred to the difficulties in teaching and learning the multiple meanings of some chemical reaction topics. This kind of work marks the importance in documenting PCK and using it in teachers' educational process.

The methodology used in this research was taken from LOUGHRAN, MULHALL & BERRY (2004), viz. Content Representation (CoRe) and Pedagogical and Professional experience Repertoires (PaP-eRs). Both tools seem to be a good way to capture and portray what is going on in the educator's mind when teaching in classroom. The reason is that CoRe gathers their teaching objectives, the knowledge of alternative student's conceptions; problems that commonly appear when learning; effective sequencing of topic elements and important approaches to the framing of the ideas; use of appropriate analogies, demonstrations and examples; and insightful ways to assess understanding. These are the main aspects of PCK analyzed in this paper. On the other hand, PaP-ers extend the CoRe information and illustrate how such knowledge might reflect effective classroom practice.

DE JONG, VEAL & VAN DRIEL (2002) and have presented their conclusions of a review of the literature on the knowledge base developed by science teachers and have recently written on PCK for the particular topic of using particle models in teaching chemistry (DE JONG, VAN DRIEL and VERLOOP, 2005).

The general research question guiding this investigation was: what content of PCK can be identified with experienced science teachers of the high school level from different institutions, using different types of curricula regarding the topic of the particulate nature of matter? It is important to know whether PCK is relatively independent or not of the teachers' professional background and the curriculum used in their classroom. If it is dependent, that could be a justification for focusing on the practical aspects of the curriculum while training teachers of any given institution.

METHODOLOGY AND SAMPLE

Our sample consisted of three sets of high school science teachers:

Five work at the high school system of the National University of Mexico, where they teach an STS type of curriculum. All of them are studying for a Masters Degree in Chemistry Education. They were selected on the basis of having the highest Subject Matter Knowledge in the Master's selection examination. This is the youngest group of teachers (36 years old is their average age). Their teaching experience spans from 2 to 12 years. We will identify this group as MADEMS, the acronym of the master degree they attend (*Maestría en Docencia para la Educación Media Superior* [Master Degree in High School Teaching]).

Five come from the *Instituto de Educación Media Superior del Distrito Federal* [Institute of High School Education of the Federal District]), México City, a public institution that works within a constructivist approach where, besides the objective of learning knowledge, the development of skills and attitudes is also emphasized. Their colleagues acknowledge the selected teachers as people who work with a clear constructivist vision. Their experience ranges between 12 to 18 years. We will call this group IEMS, the acronym of the institute.

Six work in the 'Polimodal level' of public and private high schools in Argentina. They work with a problem solving curriculum emphasis and are considered by students and academic authorities as 'excellent' teachers. They have taught chemistry for an average of 19 years. Six teachers have a university degree, which is not usual in Argentinean teachers'. We will refer to this group as NEP, for the name of the level of this system in the province of Buenos Aires (*Nivel de Educación Polimodal* [Polimode Education Level]).

In the following three paragraphs we present some of the main characteristics of the curriculum taught by the three groups of Latin-American teachers, to contrast with them the particularities of their PCK:

MADEMS teachers have the following five curricular units for Chemistry I and II related with the STS dimension, that reflect global necessities, not merely a set of chemistry topics: 1: Water, essential compound; 2: Oxygen, active air component 3: Soil, source of plant's nutriments; 4: Food, provider of substances for life; 5: Medicines, chemical products for health.

IEMS teachers follow an objective related curriculum. The lines on three objectives related with the theories and models on the particulate structure of matter are the following:

"Students will value the importance of models for Chemistry, in particular, the kinetic-molecular model to explain the three states of matter; students will recognize the atomic theory of Dalton as a tool to represent elements and compounds, comprehending chemical changes as a new accommodation of atoms; students will identify the structural models of matter that contributed to the development of atomic theory".

For NEP teachers the curriculum tends to teach students to solve problems:

"The school must also teach students to think how to solve problems, to discuss the different viewpoints that one may posses about the problems, and to present a responsible attitude in face of the different situations in their working and civic life".

Teaching has an important component of "*know how*", not disregarding the conceptual aspects of "*know*" and those of an integral formation in the "*know to be*". It is intended to form citizens prepared for the world of work.

In short, we have chosen three educational institutions that make emphasis in different curricular purposes: in MADEMS, a STS approach; in IEMS, the constructivist perspective; and in NEP, problem solving. Therefore, we will be able to compare the PCK of the three groups of teachers in order to analyze whether the curricular structure and the professional experience have any influence on it, or not.

In each one of the three groups of teachers, personal interviews with each one of its members were developed to orientate them to elaborate their individual CoRes. This way they would develop and write their own vision on how to teach the topic of 'the particulate nature of matter'. After the interview, all teachers received a CoRe questionnaire to write explicitly the central ideas for presenting the topic, followed by the eight CoRe questions, viz.

Table 1
Questions regarding each one of the central ideas for teaching the topic

1. What 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 your 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 likely range of responses).

Afterwards, the teachers of each institution were joined in a collective effort of discussion in order to arrive at a consensus version of the CoRe central ideas, and invited to rewrite their answers collectively to the CoRe questionnaire. By this time it was obvious to us that it was not useful to view PCK solely as something residing in an individual teacher, because different but complementary aspects of PCK are revealed through exploration with groups of teachers (CoRes) as opposed to individual teachers (PaP-eRs). Definitively, the process of discussing in order to arrive at a consensus CoRe enriches the individual responses because of the argumentation given and exchanged. Nevertheless, we take into account individual CoRes as well as consensus CoRes in this research.

It is crucial to emphasize that CoRe is both a research tool for accessing science teachers' understanding of the content as well as a way of representing this knowledge. Therefore, we used CoRe as an interview tool with groups of science teachers to elicit their understandings of important aspects of the content under consideration and its teaching, as well as the use of the outcomes of these interviews as the representation itself.

Data analysis and results

We are going to split in four steps the analysis of the research question mentioned in the introduction, and arrive at the conclusion that PCK seems to depend on the personal and professional experiences of teachers as well as on the curricular emphasis used in their institutions. The first one has to do with the comparison of the central ideas declared by each group of teachers; the second with the collective answers they gave to the CoRe questionnaire; the third with the individual CoRes of three teachers, one of each system, as representatives of the curricular, professional and pedagogical influence on their PCK; and the fourth mentions the PaP-eRs, individual efforts that were developed in this study.

Comparison of central ideas exposed by four groups of teachers in their consensus Content Representations (CoRe)

The central ideas expressed by the three groups of Latin American teachers have been joined by affinity in table 2, where the Australian science teachers interviewed by LOUGHRAN *et al.* (2004) have also been presented.

Table 2. Sets of central ideas from the three Latin American high school systems' science teachers and the Australian science teachers gathered by their similarities

	MADEMS	IEMS	NEP	Australian Teachers
1	Matter is made up of small particles.	Matter is made up of particles.	Atom divisibility.	Matter is made up of small bits called particles.
2	The space among particles is empty.	Discontinuity.	Discontinuity of matter.	There is empty space between particles.
3	Particles are constantly moving in a random way.	Particles are moving.		Particles are moving (their speed is changed by tempe-rature) and they appear in a certain arrangement.
4				Particles of different subs-tances are different from one another.
5				There are different kinds of particles that, when joined, are different again.
6	Applications of the structure of matter in solids, liquids and gases; its changes of state, its energetic changes, vapour pressure, surface tension, temperature, etc.	Macro-micro relationship.	Relationship between structure and physical and chemical properties.	
7		States of aggre-gation of matter		
8		Existence of a relation among P, V and T.		
9	Particles are linked together through bonds.		Chemical bonding.	
10	Properties observed in substances are the result of interactions among particles and not properties of each individual particle.			
11	Dimensions of particles are constant, independently of the state of aggregation.			
12		Models are very important in chemistry.		The concept of a model is used to explain the things we observe.
13		Scientific theories and models evolve, constantly		
14	Conservation of matter.			There is conservation of matter. Particles do not disappear or get created; rather, their arrangements change.
15			Relationship between matter and energy.	

The five first rows of table 2 show the five central ideas related to particles. The three sets of Latin-American teachers share the central ideas of matter discontinuity, the existence of particles and empty space among them (rows 1 to 3).

Two of the particle central ideas belong only to the Australian teachers (rows 4 and 5) and have to do with particles as constituents of different substances and with their combination.

Another three central ideas (rows 6 to 8) have to do with the microscopic explanations of bulk properties of substances, aspect common in the three Latin-American groups but that doesn't appear in the Australian. It is connected with the applicability of kinetic-molecular model.

The ninth central idea refers to chemical bonding and is shared by teachers from MADEMS and NEP. The other two ideas (rows 10 and 11) are not related with central themes of the content; they are not part of SMK but rather aspects that have to be considered when teaching the topic. Rows 12 and 13 relate to aspects of modelling in science and were mentioned by IEMS' and Australia's teachers. Without any doubt this is a good moment to emphasize science's working with models. It is inappropriate to ignore it in a course in which scientific inquiry is a main topic, an aspect that seems only important to IEMS' teachers among Latin-Americans. This fact may be a result of the relevance that the 'Nature of Science' as part of the constructivist scheme.

Central idea 14^th^, related to matter conservation, is shared by teachers from MADEMS and by Australians. Finally, central idea 15^th^ that has to do with the matter-energy relationship only mattered to NEP's teachers. If something can be appreciated as particular in NEP's teachers is their preoccupation with the relationship of chemistry basic concepts and its applications.

CoRes comparison

The related ideas of the Latin-American proposals are grouped by topic and the most important points are discussed. We write in bold type the topic addressed in the analysis.

In the CoRe's body, though not in their central ideas, all Latin-American teachers make reference to the utilization of *models* in teaching. However we have to state that those who refer more clearly to the topic are teachers from IEMS, surely due to the constructivist nature of their curriculum, with an emphasis in scientific inquiry. They say:

a) Models are a way of representing a group of experimental evidences.
b) Each model has its contributions but also its limitations.
c) Models serve to express what is observed for others to understand.
d) Students have to know clearly that a model is a representation of a concept or a process and that we are working with models all of the time. They should connect their perceptions with the models.

The proposal of using the topic of "models" to develop a *black box activity* is very common. Regarding their teaching procedures MADEMS teachers tell us:

It is important to propose an activity that resembles model construction, such as the black box. This activity stresses the need for the construction of a model that allows the description and explanation of the observed phenomena, given the limitations in touching and directly watching matter constitution.

One of the PaP-eRs that we have prepared for this study has to do with this point. We have entitled it "Elaborating a model" and will be described in the section on PaP-eRs.

From the knowledge of difficulties of students and the way teachers use such knowledge when elaborating teaching-learning situations, we can extract the following *alternative conceptions* detected by MADEMS teachers:

a) The biggest problem is that one has to talk about, imagine and understand something that cannot be seen. When students observe their surrounding world, they perceive a continuum in it; that is why it is difficult for them to accept the actual existence of discrete particles in constant movement. The small size of these particles makes the students doubtful of their existence.
b) The research studies about alternative conceptions show that students have great difficulty in understanding the particulate nature of matter.
c) The kinetic-molecular model implies a different vocabulary with very specific meanings. Scientific language is abstract.
d) The Aristotelian horror to vacuum is in fact a reality in students' minds. They cannot understand that if everything is composed of atoms and that these atoms are mainly empty space, how come for instance a mountaineer climbs rocks (made of atoms) and safely secures his gear on them?
e) In the case of gases, because they can't be seen, students can't conceive of the presence of particles.
f) Students think that properties like colour, smell, magnetism, hardness, reactivity, etc., are attributable to isolated atoms in a substance (i.e. lead atoms are grey and solid, hydrogen atoms are flammable and gaseous, neon atoms are fluorescent, etc.).

The above is a good summary of the main alternative conceptions on this topic. These teachers have recently studied this theme in their Master studies. They show a vast knowledge on this point, reflecting their professional background and studies on PCK.

In relation to the *educational strategies* that have to be used when explaining to students the particulate nature of matter, there are varied approaches. We have selected this point as one of capital importance, because it has been included as a principal point in PCK description. We will discuss the three institutions comments on this topic.

Teachers from NEP mention the following strategies:

a) Electrolysis experiments.
b) The modern microscopic techniques and showing students the best pictures of atoms and molecules.
c) To elaborate questionnaires, experimental work, and lab reports.
d) Having group discussion about the results.

The last two ideas show resemblance with the problem solving nature of the NEP's syllabus.

The second PaP-eR that we have prepared for this study has to do with point b) in the list. We have entitled it "Using microscopy to teach structure of matter", a good idea usable since 1990 for students to loose the fear of the atomic nature of matter, where the first scanning tunneling microscopy (STM) photos were obtained.

Teachers from MADEMS indicate the following strategies, typical of an STS syllabus approach with a strong laboratory emphasis and a robust knowledge of several didactic projects on the topic of the particulate nature of matter:

1) Short experiments and class demonstrations that suggest presence of particles such as those in *Children's Learning in Science project* of Leeds University (CLIS, 1987).
2) Encourage the use of imagination. Utilize for this purpose the "magic glasses" that are good for "seeing" the microscopic detail, such as is used in *Matter and Molecules project* of Michigan State University (MAM, 1988).
3) They should take a paper and cut it in very small pieces, the smallest they can. Ask them: what if we keep on cutting one of it a 1000 times more, is there a limit?
4) Using everyday life examples, in order to relate matter properties with their structure and stimulate problem solving ability and critic thought.
5) It is advisable to devote some time to the analysis of the fuzzy limits between granulated and powdered solids, and liquids; and to make activities such as pouring liquids and solids from one container to another. Or to observe tiny crystals of powder, talcum, salt, sugar, under a magnifying glass, and to arrive to the conclusion that in liquids those particles cannot be seen, though they have a similar behaviour. This may help to interpret the existence of very little particles in liquids. This description of the fifth strategy is outstanding.

Teachers from IEMS propose the following as alternatives, which reflect their inquiry based teaching of chemistry, full of experimental work:

a) To make students perform a series of activities on the concept of "model".
b) Suggesting readings about physicists' work on kinetic theory and the philosophical conception of an indivisible particle.
c) To highlight through microscopic observation the fat drops in milk or cream and to see the movement of something that is apparently static.
d) To make experimental activities with gases: diffusion, solubility, compression, etc. (for example the penetration of dye through ice or the deflation of a balloon containing hydrogen).
e) To perform diffusion experiments, such as spreading and smelling perfume inside the classroom or pouring a drop of ink in a glass of water; this allows students to have a good grasp of the idea that particles are moving.
f) To carry out experimental activities such as those with syringes containing air and water by applying different pressures on them to observe a change in volume, or not.
g) Heating a laboratory flask, that has a balloon over the rim, thereby observing that the balloon blows up.

In the two strategies recommended by MADEMS and IEMS' teachers, a lot of experience with simple experiments was used to detect the complexity of particulate nature of matter. The third PaP-eR that we present in this study has to do with point d) in the last list. We have entitled it

"Other ways to see the world".

Finally, in relation to the ways to *assess learning* a whole series of proposals is also provided.

For example, teachers from Argentinean NEP tell us what they do, related with their problem solving curricular emphasis:

a) To make a list of simple but everyday substances and make students investigate and discuss how they are formed.
b) To do guided answer activities, true-false exercises with justifications and examples.
c) Construction of concept maps.
d) Developing cases' studies.
e) To present study guides, questionnaires, activity guides, crosswords, coupling or multiple-choice activities.

A consensus CoRe of each group of teachers closely related to their curricular emphasis has been found, but we can not say that one of them is better than the other. As LOUGHRAN, MULHALL & BERRY (2004) comment, "*a CoRe derived from one group of science teachers should not be viewed as static or as the only/best/correct representation of that content. It is a necessary but incomplete generalization resulting from work with a particular group of teachers at a particular time*".

Individual-CoRes. Relation with the professional and curricular experiences of teachers

The last section includes the consensual CoRe analysis of the teachers from the three Institutions. In this one we round off with the textual quotes of some Individual-CoRes and we express their relationship with the professional and curricular experiences of the teacher. An example from each institution is included:

Teacher "α" works at the university as well at the secondary level in the Argentinean NEP; her experience in university teaching reflects her deep knowledge of chemistry and the importance that she gives to teach models in the subject of 'structure of matter'. That is why in her CoRe she says:

The subject is one of the big ones of chemistry; it gives the base to understand all other subjects, and helps to introduce the concept of 'model'. On the basis of that, we can see how the structure determines the macroscopic properties and how it is possible to create simple models in enclosed conditions (like the kinetic molecular one) that allows students to obtain simple mathematic expressions for experimental measurable variables. Structure of matter is a very appropriate subject to emphasize the general importance of models in the field of sciences.

Teacher "β" is from MADEMS group and teaches in a laboratory-classroom for 25 to 30 pupils, arranged in groups of 4 students on each table with gas and water installations. His professional experience in this site is notable when he proposes experimental strategies to teach, for example, the aggregation states of matter from an STS point of view, working with every day materials:

It results useful to work in the laboratory-classroom with solids of different characteristics: bricks, wood, cork, metals, stones, mirrors, glasses, sponges, rice, flour, wool, detergent, sugar, salt, mud, sand, dough, plasticine, talcum powder, etc. Or liquids, as water, milk, oil, juices, vinegar, alcohol, honey, liquid detergent, shampoo, etc. Or gases inside balloons or perceivable through fanning or blowing. In this way it is interesting to explore the confusing border between powdered and granulated solids and liquids.

We can say that this teacher promotes secondary school students' understanding of the relationship between phenomena and corpuscular entities, as was one of the objectives in the research of DE JONG, VAN DRIEL & VERLOOP (2005).

Teacher "χ" has seventeen years of teaching experience in high school, but she also has worked during ten years at the university. The last seven years she has been working in IEMS, with its emphasis in a constructivist perspective of learning. She has taken several courses for teachers to improve her constructivist vision:

It is important to teach from this perspective, what means to centre education on students, because they are the constructers of knowledge.

She also tells us the following, which has to do with the inquiry nature of her teaching:

The way in which those particulate concepts are dealt with the classroom makes the students to consider a new vision of the world. It opens to them a new way to see the same problem, the possibility to explore. It is very important that teachers unlock this opportunity to the students, not in a dogmatic way, but by analyzing why we have arrived at that idea.

As can be seen, we have found a great variety of ways to approach the topic of particulate structure of matter in the three groups of Latin-American teachers, though we may say that these views can be considered complementary to each other.

PaP-eRs developed in this study

PaP-eRs offer a way to apprehend PCK's holistic nature and complexity. They are narrative essays about individual teachers developed from classroom observations or interviews. They have the ability to express a "discursive whole" by explaining in a text what a teacher considers as primordial actions when teaching.

The three Pedagogical and Professional Experience Repertoires (PaP-eRs) that the researchers consider as the most representative samples of individual teachers' PCK are shown in table 3 and they are offered on request by e-mail to the interested reader.

Table 3
List of the three PaP-eRs developed in this study.

PaP-eR	Teacher's institution
1 "Elaborating a model"	MADEMS
2 "Using microscopy to teach structure of matter"	NEP
3 "Other ways to see the world"	IEMS

A brief description of the three PaP-eRs is the following:

The first PaP-eR refers to a models' theme evaluation activity. It is not intended here that students find out the exact contents of the "black box", but rather to infer the nature of the objects that seems to be inside, as well as to generate arguments to validate the asserted conjectures and finally to make reasoned predictions. It is more important the formation of an inquiry attitude during the exercise than contrasting the model reached with reality. That is why it is insisted as a condition "not to ever open the box".

The second PaP-eR talks about the information that may be obtained by using images of STM. This is a technique that was reached at IBM Research Laboratory in Zurich, and that was worth the 1986 Physics Nobel Prize to Gerd Karl Binnig and Heinrich Rohrer. It is shown how STM functions and how the images taken with it give certitude and confidence to students about the existence of atoms and molecules. This helps to face the difficulty of working with very small objects and with the concept of vacuum, which require a high degree of abstraction.

The third PaP-eR has to do with the way in which students see the world and trays to show them other ways of doing it. The PaP-eR has six experiments that show that matter is formed by small particles separated by empty space. The six experiments are not original, with the one exception, that of the diffusion of $KMnO_4$ crystals in an ice piece, which the authors have not found reported in the literature.

CONCLUSIONS AND IMPLICATIONS

The first conclusion is that a rich Content Representation of a group of experienced teachers may be of allurement to teachers and teacher educators interested in the analysis of key PCK characteristics: teaching objectives, alternative student's conceptions; teaching and learning problems; effective sequencing of topic elements; use of appropriate analogies, demonstrations and examples; and ways of evaluating the understanding. This kind of analysis and discussion will be very profitable for teacher educators, as it represents an intense immersion on the desirable elements of teacher action. Although the present study is restricted to the topic of the particulate nature of matter, the results support the importance of paying attention to the richness of teachers' PCK, particularly when designing and enacting in-service courses for science teachers in any other topics.

Thus, one interesting implication of the CoRe elaborated with a group of teachers is to use it for discussion and argumentation as a teachers' training activity in workshops with different groups of teachers. In spite of the fact that PCK is constructed mainly by teaching practice, using the CoRes of distinguished teachers in this kind of workshop will be helpful in the formative process because those subjected to the experience will gain confidence and reduce the newness and surprise when facing similar teaching challenges. They will have a greater response capacity in front of situations that could otherwise be overlooked.

The second conclusion is the importance to communicate that the CoRe and PaP-eRs techniques proposed by LOUGHRAM, MULHALL & BERRY (2004) are perhaps fruitful ways of documenting a set of teachers' PCK.

On the onehand, the CoRe reveals several issues contained in PCK, relatively easy to gather with a short questionnaire that can be applied first individually and then in a set of sessions to the complete group, making the discussion and negotiation of what portions of the individual CoRes convince the other teachers of the group to form part of the consensus CoRe. This kind of analysis seems to be an interesting way of discussing the ideas expressed in each one of the teachers individual CoRes, which enriches the discussion until arriving at a consensual version of it. In this process, in which everyone would concede in face of the arguments of the others, the knowledge, impressions, didactic and evaluation strategies from all the participants could be summed up. Nevertheless, one can make the analysis by also using the individual Cores. Another useful idea is to ask teachers to repeat the exercise of answering the CoRe questions, but now with the central ideas gotten by consensus in a group session. In this way, all the individual CoRes would then be headed by the same set of central ideas, which would make much more comparable the set of individual CoRes.

On the other hand, PaP-eRs discover the precision of the way a teacher acts in the classroom, and can be recovered with his or her primary notes, complemented afterwards with those of the researchers during class observations and interviews. The PaP-eRs show clear examples of what teachers with a developed PCK may present in action with their students. It is important to note that one PaP-eR alone is not enough to depict the complexity of the knowledge around a given content, but showing a collection of PaP-eRs of CoRe related areas becomes crucial to enhance some of the different mixed ingredients of PCK in the field.

The third conclusion is that, although central ideas expressed in the consensus CoRes by the three groups of Latin-American teachers were strictly different, that does not imply that one of them is the correct or the better one, because as Mulhall, Berry & Loughram (2003) state it there may be more than one valid CoRe for each topic. If we would try to arrive at a single consensus CoRe of the 16 Latin-American teachers, perhaps several PCK's features, mainly those of local importance, would have disappeared along the way.

The fourth and final conclusion is that we have made evident the presence of constructivist and inquiry type of approaches in IEMS' CoRe; the STS focus and the profound knowledge of alternative conceptions in MADEMS' teachers; and the problem solving, the relationships among different scientific concepts and its applications, and preparation to work emphasis in NEP's. The authors of this study might now assert that PCK is evidence of the emphasis given in the curriculum and of the professional background of the teachers. A final implication could be that it is very important for teachers' training activities to consider the curricular emphasis and the pedagogical orientations, due to its influence in the development of PCK and of pedagogical knowledge regarding instruction of high order thinking (Zohar, 2004).

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Deficiencias en la enseñanza habitual de los conceptos macroscópicos de sustancia y de cambio químico

Usual teaching deficiencies when explaining the macroscopic concepts of substance and chemical change

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Resumen

La investigación en didáctica de las ciencias ha mostrado que los estudiantes tienen importantes dificultades en la comprensión de los conceptos de sustancia, sustancia compuesta y cambio químico. En este trabajo pretendemos ver si estas dificultades conceptuales también se presentan en la enseñanza habitual de la química. Para ello se ha llevado a cabo un diseño múltiple y convergente mediante encuestas a muestras de profesores de física y química de secundaria en formación y en activo y una red de análisis de 27 ítemes aplicada a más de un centenar de libros de texto. Los resultados encontrados muestran que la enseñanza no da importancia a la definición operacional (macroscópica) de sustancia, no explicita las diferencias macroscópicas y microscópicas entre sustancia compuesta y mezcla de sustancias simples y, olvida la introducción del concepto de elemento químico, que permite explicar la conceptualización macroscópica de reacción química como cambio sustancial.

Palabras clave: *deficiencias macroscópicas, enseñanza, sustancia, compuesto*

Abstract

Research in Science Education has pointed out that students have significant difficulties to understand the concepts of substance, compound substance and chemical change. The aim of this work is to find out whether these conceptual difficulties are present in the usual teaching of Chemistry, too. To do this, a multiple and convergent design has been carried out. It is composed of some questionnaires given a sample of different physics and chemistry secondary teachers and a data network with 27 items applied to more than a hundred textbooks. Results found show that teaching gives no importance to the operational macroscopic definition of substance, nor makes explicit the macroscopic and microscopic differences between a compound and a mixture of simple substances; and forgets the introduction of the concept of chemical element which permits to explain the macroscopic conceptualisation of a chemical reaction as a substantial change

Key words: *macroscopic deficiencies, teaching, substance, compound.*

INTRODUCCIÓN

La investigación en didáctica de las ciencias ha mostrado en los últimos años un interés especial por el tema de la estructura de los materiales y las transformaciones de unas sustancias en otras, como se pone de manifiesto en la gran cantidad de artículos escritos al respecto, entre los que podríamos mencionar los referentes a la dificultad para diferenciar entre material y