EPISTEMOLOGICAL AND ONTOLOGICAL ASPECTS IN SCIENCE TEACHER EDUCATION

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INTRODUCTION

The aim of this paper is to present a state of the art about the presence of epistemology and ontology in science teacher education. So, the work will have the nature of a review of the main literature related to the theme. We will show that in relation to epistemology a general consensus exists about the necessity of this subject being present as an important component of any proposal for science teacher education. In relation to ontology, there are not many references which address the topic explicitly; but in our opinion, there evidence enough to make us think of the necessity also of including this topic as one essential part of science teacher education programs. We will try to justify our point of view, in the hope of opening the theme for discussion, and for future research.

1. FROM WHERE AND WHY OF EPISTEMOLOGY?

1.1. Epistemology and Science Education

For more than 40 years there have been demands for the introduction of the philosophy and the history of sciences into the school curriculum, connecting these themes with the curriculum content and with the way of teaching/learning the different subject matter. We can find the first context **where** this issue emerged in the *"Curriculum Reform Movement"* (Bruner 1960).

In the sixties the "Curriculum Reform Movement" expanded, and it was characterized by a special emphasis on including the history of science and the "scientific method" in the curricula developed according to the new ways of understanding the teaching and learning of science, imposed by this movement. For instance, we can remember here the so-called *"alphabet curricula"* (PSSC- Physical Science Study Committee, CBA – Chemical Bond Approach Project, CHEM- Chemical Education Material Study, BSCS- Biological Sciences Curriculum Study, SCIS- Science Curriculum Improvement Study) etc, all of them published in the USA in the early sixties, and specially to this respect *The Project Physics Course* - or HPP for *Harvard Physic Project* -; and also, the different Nuffield Projects, published in the UK from the mid sixties.

The "alphabet curricula" produced in the USA were evaluated in the mid seventies, in several research projects sponsored by the National Science Foundation). No one of these researches paid specific attention to the impact of including the history of science, and the "scientific method" in the new curricula; and neither to the nature of science reflected on the scientific contents and methods to acquire knowledge exposed in the new materials[1]

In their seminal paper *Epistemology and Science Education,* Cawthron and Rowell (1978) analysed these aspects of school science, arriving at this conclusion: *"In more specific epistemological terms, school science generally projects an image of science which can be called empiricist-inductivist. Although existing in many variants it is basically founded on a conception of scientific method as described by Bacon: a well-defined, quasi-mechanical process consisting of a number of characteristic stages"* (p 33). As a consequence, they propose new perspectives to introduce modern epistemologies into Science Education, namely, Popperian and Kuhnian approaches, and claim that *"teacher training institutions need to look more closely at these matter and to employ professional staff well versed in both methodology and philosophy of science"* (p 51). We can say that this paper was the starting point for many authors thinking and writing about these subjects,

[1] A summary of these evaluations ca be found in Gutierrez 1987.

from those of “the first wave” represented by Rogers (1982), Summer (1982), etc, until more recent authors, such as Hodson 1993, Duschl and Hamilton 1994, Matthews 1998a, etc.

So, this is not a new topic. And today it is a very active field of research, as can be observed in the numbers and quality of papers published, i.e. in the specialized research journal *Science&Education*, since 1992, and the different national and international groups and institutions working on this area[2].

1.2. Epistemology and Learning

Here we have to switch our mind to another subject: that of spontaneous thinking, or pupils’ alternatives ideas in sciences. This is a second step to enter into the context of our theme.

As it has been said elsewhere (Gutierrez and Pinto 2001), apart from the merit of describing students’ spontaneous thinking, which is a value in itself, researchers have reached the conviction that this field of research can offer nothing new, at least they may explain its origins or what is underneath it. These feelings have given way to different lines of exploration, such as that of relating students’ spontaneous conceptions with the epistemological view of science that students hold. The idea is that an inadequate epistemological belief could possibly act as a constraint to the learning of the right scientific concepts (Hammer 1994, Roth and Roychoudhury 1994).

The research in this field has shown that most students hold a positivist-empiricist view of the nature of science, based on “facts” and “objective observations” (Désautel and Larochelle 1998b, Tsai 1999, Wiser and Amin 2001), and that this view conditions the quality of their knowledge and understanding of scientific concepts, models and theories.

1.3. Epistemology and Teaching

How do the students construct their epistemological beliefs?

It is quite obvious that they could come from different sources. But there are many researchers convinced that the most decisive one is the influence of teachers’ beliefs about the nature of science and the way science is taught. So researchers started testing this hypothesis, studying the epistemological view of teachers and their students, and found that a close relationship exists between the two. See, for instance, the studies of Lederman 1992, Moje 1995, Hashweh 1996. In all these papers most teachers are described as holding an epistemological view of science that is positivist-empiricist or empirical-realist, not very different from that of their students.

Data from other researches have supported the anterior findings about teachers’ epistemological view, i.e., Gil and Pessoa (1998), Porlan (2002), Pro (2003). Nevertheless, some studies have shown that teachers do not hold an epistemological position necessarily coherent with a unique epistemological tradition (Koulaidis and Ogborn 1989, Lakin and Wellington 1994).

The relationship between teachers’ and students’ epistemology is widely accepted. In current studies, authors warn about the epistemological view of teachers and their influence in teaching. Thus,

Mueller and Wavering (1999): *"The view of teacher toward the nature of science is a major factor in determining the way that teachers present the material to students"* (p 1148);

Séré et al 1998: *"Any approach to teaching and learning Science is influenced by epistemological considerations concerning the structure and the object of the scientific knowledge to be taught"* (Chapter 5, section 5.3);

[2] An excellent review of this theme ca be found in Matthews 1998b.

Gil and Pessoa 1998: *“Teachers’ spontaneous epistemology constitutes a serious obstacle to the renewal of science teaching in as much as it is accepted uncritically as ‘common-sense evidence’. ”* (p 9);

Craven and Penick (2001): *"teachers' views of the world... have direct impact on the way they teach"* (p 3);

Désautels and Larochelle (1998a): *"Willingly or unwillingly, consciously or unconsciously, all science teaching practices embody an epistemological posture, among other things*" (p1). These authors alert of the *“the perverse effects of an epistemological posture in teaching"* (p 2) when that means to teach the scientific content as *"knowledge that exists by virtue of itself, that has emerged from nowhere, so to speak",* presenting a *"thingifying vision of science"* (p 2).

It is necessary to have in mind that there is not always coherency between what teachers say about their beliefs and their behaviour in classrooms. Some evidence from literature support this point (Mellado 1998, Liu et al 1998). In the STTIS Project (1997-2001) we found teachers behaviour in classroom very different from their explicit intentions stated in interviews before teaching. In my opinion, **what teachers really do believe** is what influences their actions in classrooms, not **what they say** about their beliefs. As expressed by Waggett (2001): “*Stated beliefs do not necessarily manifest into desired practice. The field of education is replete with jargon which is not difficult for students to parrot to professors (Brockmeyer, 1998). Instructors responsible for the education of future teachers* [and teachers themselves, it could be added] *must not assume that if students are able to use words such as "inquiry" and "constructivism", that students fully understand how these translate into effective science instruction”* (p 47)*"*.

The relationship between teachers’ epistemological assumptions and teaching, answers the **“why”** of the interest in the study of this subject in the field of the didactic of science.

2. EPISTEMOLOGY AND TEACHER EDUCATION

As we noticed before, Cawthron and Rowell (1978) asked in their paper for “*professional staff well versed in both methodology and philosophy of science”* to be present in teacher education institutions. Knowing the context in which the paper was written, it is not forcing the thinking of the authors to say that what they really mean with the presence of this professionals was that in the institutions where the curricula were designed and developed, somebody could examine and thus prevent these curricula from transmitting an inadequate image of science and of the scientific methodologies. After 35 years it is clear that today we should ask for more than that, particularly in relation to science teacher education, as we will see in the following sections.

2.1. Pre-service and In-service Teacher Education

The evidence coming from research about the image of science and scientific knowledge held by many teachers have surprised and worried the professionals in the didactic field. As a consequence, many researchers have insisted on the necessity of explicitly introducing the epistemology of science in both pre-service and in-service teacher education courses. For instance, Lakin and Wellington 1994, Désautels and Larochelle 1998b, Gil and Pessoa 1998, Séré et al 1998, Waggett 2001, Porlan 2002. It is interesting to quote from some of them:

“Previous reports have pointed out the pressing need for INSET in relation to the introduction of the nature of science into science curricula [...] to give teachers the opportunities and guidance in exploring their own views on the nature of science. For many teachers their participation in this study marked the first recognition that they have a "philosophy of science". ***The word "philosophy" has for many teachers become a threat rather than something they have that needs drawing out"*** (Lakin and Wellington 1994 p 187-188). [our remarks]

"From this perspective, a key issue in the education of science teachers involves creating the requisite conditions by which teachers can: 1) critically and reflexively problematize their own epistemological posture; 2) consider other potentialities; and whenever possible, 3) break the vicious circle permitting reproduction of traditional school epistemology concerning science" (Désautels and Larochelle 1998b p1).

"Implications are numerous for teachers' training where the didactical activity should be framed in an epistemological context strongly related with the disciplinary and historical aspects" (Séré et al 1998, Main Research Results and Conclusions, Section 1.2.2).

In fact, many institutions have adopted scientific epistemology in their proposals for science teacher education. Research in the field has shown that *when the epistemological beliefs of teachers are properly elicited and challenged* (mainly through reflection and discussion adequately designed and put into practice in training courses), *they easily acquire a critical view about epistemology and about their own epistemology* (Désautels and Larochelle 1998b, Gil and Pessoa 1998, Porlan 2002).

3. FROM EPISTEMOLOGY TO ONTOLOGY

3.1. Students' spontaneous conceptions and ontology.

Research has shown severe difficulties in overcoming students' spontaneous conceptions. The most widely used strategy designed in classrooms to address this problem has been the "conceptual change approach". Recent reviews of this issue can be found, for example, in some monograph, such as *Learning and Instruction* (1994) *22* (1); (2001) 11 (4-5), *Enseñanza de las Ciencias* (1999) *17* (1); in the book *New Perspectives on Conceptual Change,* edited by Schnotz et al (1999); and the two papers by Duschl and Hamilton (1998), and Hewson et al (1998) appeared in the last *International Handbook of Science Education* (Fraser and Tobin 1998). The main conclusions of these researches are that we still lack of a description of the mechanisms underlying conceptual change processes (Gutierrez 2001). Or, as stated by Mason, the editor of the monograph *Learning and Instruction* (2001): *"The findings of these studies highlight the need to refocus our efforts on ways to stimulate and support conceptual change in science domains by considering the basic cognitive processes underlying knowledge revision in formal educational settings".* (p 260). And the key question continuous to be the following: *"What are the driving forces behind conceptual change that can be activate and in what ways?"* (Mason 2001, p 260)

As it is well known, conceptual change approaches take the theoretical background first established in 1982 by Posner et al (the PSHG model). Despite the revision made ten years later by Strike and Posner, the model still rests primarily on the analysis of two components: the *status* of students' conception or theory; and the *conceptual ecology* (epistemological commitment, and metaphysical beliefs about the world). For the results of the research above shown, this analysis reveals itself insufficient: They have not led to the desired finding. That could mean that either the object or the method of the analysis has failed; or both.

We can say that epistemology is too wide a construct as to offer enough insight about students' thinking. There must still be something beneath it.

From a theoretical point of view, under every epistemology – provision of "truth criteria" for maintaining a coherent, reasonable and generalisable vision between data and beliefs, or between evidences and theories (Bunge 1980) – lies an ontology – convictions concerning the entities that exist in the material or conceptual field, on which the relations that stated by laws and theories are built (Estany 1993) -. Without an adequate comprehension of the conceptual entities or objects on which these laws and scientific theories are built, it is impossible to have correct knowledge either of the mentioned theories, or of the nature of science itself.

In practical terms, to say to a teacher that one student is "positivist" or "inductivist" provides information about the kind of criteria he/she uses to validate some knowledge as true (this is the object of epistemology). But it does not tell him the characteristics that this student assigns to a certain concept or entity, in such a way as to give information about the nature, the functioning, the role, or the properties the student attributes to that concept or entity. This is something that ontology can offer.

From an ontological perspective, the so-called students' "conceptual errors" are a mere expression of an inadequate scientific ontology. Thus, if we study students' spontaneous thinking from this point of view, we are doing a finer grain analysis of their conceptions, and we try to support our findings on a deeper theoretical background than that which is normally used (if any) in this line of research. Here we can situate the works of Ogborn (1991), Mariani and Ogborn (1991), Chi and Slotta (1993), Slotta et al (1995), White (1995), Pauen (1999), Tytler (2000), Mannila et al (2001).

To this respect, we agree with the conclusion of Wiser and Amin (2001), referring to thermal physics, but adding that it can be extended to other fields of scientific knowledge:

"When learning the science view in thermal domains, the core stumbling block is ontological". (p 332).

3.1.1. Ontological analysis of students' conceptions

Ontological analysis of students' conceptions seems to represent a big step in theoretical grounding and interpreting the literature produced on this matter. It is showing its full potentiality in the field of modelling students' spontaneous thinking. It is so because its possibilities of offering a coherent sets of related knowledge, that could make some *"what", "from"* and *"why"* characteristics of students' thinking more intelligible. And if these models are dynamic in nature, they also have de possibilities of enlightening us about the "*basic cognitive processes"* that can play a role in changing these spontaneous concepts, as was asked for in conceptual change research. See, for instance, the works of Gutierrez and Ogborn (1992), Vosniadou and Brewer (1994), Gutierrez and Pinto (1997), Venville and Treagust (1998), Buckley and Boulter (2000), Gutierrez (2001).

This quick summary of the state of the art in the study of students' conceptions will give us the context in which we would like to situate our approach to the points that follow.

3.2. Teachers' spontaneous conceptions and ontology

Despite the reluctance of some people to accept the issue, data speak clearly about the existence of teachers' spontaneous conceptions which are very close to those found in students. There is a very significant fact that could leave us less suspicious, and naturally accept the issue: the last edition of the well known IPN Bibliographies about spontaneous conceptions, has the title: *STCSE. Students' and Teachers' Conceptions and Science Education* (Duit 2002). As everybody knows, the anterior titles of these Bibliographies were: *Bibliography. Students Alternative Frameworks and Science Education.* The change seems to be indicative of the actual volume of research in the area of teachers' spontaneous thinking. In the last *International Handbook of Science Education* above mentioned, two chapters are devoted to this theme, those of Cochran and Jones (1998), and De Jong et al (1998). The first reviews explicitly the issue of pre-service Science Teachers; the second makes the review, in some way as a necessity of the nature of the chapter (about *Teacher Thinking and Conceptual Change*), and is related to in-service teachers; both refer to Primary and Secondary teachers. The conclusions of the two are quite similar:

"The results described so far imply that students completing baccalaureate degrees show, at least to some extent, unorganised, superficial and inaccurate knowledge of subject mater areas. The studies depict teachers' subject knowledge quite negatively, ..." (Cochran and Jones 1998 p 711);

"In sum, most of the studies reviewed show that teachers' subject matter knowledge needs improvement, not only because of deficiencies but also because of views deviate from scientific one" (De Jong et al 1998 p 747).

Description of this spontaneous thinking, deviate from the academic scientific view, is widely described in most researches in the field, i. e., Strömdahl et al 1994; and, Tüllberg et al 1994 (conceptions of mol); Bacas 1997 (heath and temperature); Cañal 1977 (photosynthesis), Furió y Guisasola 1998 (electric field); Trend 2000 (geological time); De Manuel and Jimenez 2000 (acid and alkali); Gutierrez et al 2002 (properties of matters). But no one of them is explicitly addressed to analyse the ontological commitment of teachers' spontaneous conceptions.

3.2.1. What teachers know matters

As it happened with teachers' view of science, research literature also shows the relationships between teachers' subject matter knowledge, the way they teach, and the effects on students' learning. Several authors have remarked these results in their findings, as Strömdahl et al (1994), Tüllberg et al (1994), Lee (1995). We find particularly interesting to present here the results of some of the main reviews on this subject.

-The SALISH PROJECT I (1997), *Secondary Science and Mathematics Teacher Preparation Programs: Influences on New Teachers and Their Students*. This research project was sponsored by the USA Department of Education, and the Office of Educational Research and Improvement (OERI). The main aim of the project was to bring together nine institutions that prepare science and mathematics teachers to study influences of new teachers and their students. In the *Executive Summary* of the Project one section is devoted to *"Linkages"*. One of them is stated as follows:

"Linkages were found among new teachers' knowledge and beliefs systems and classroom performances, and performance of their secondary school students" (p 3).

-CSMTP Report (2000), *Educating Teachers of Science, Mathematics and Technology: New Practices for the New Millenium.* This report was prepared by the Committee on Science and Mathematics Teacher Preparation. National Research Council (USA), with the aim of providing *"guiding principles"* to teachers, governments, universities, schools, and other professional and disciplinary organizations, *"on which further action to improve K-12 teacher education in science, mathematics, and technology should be based"* (Executive Summary p 7). In relation to our theme, the Report points out:

"In reviewing the literature, the Committee on Science and Mathematics Teacher Preparation (CSMTP) found that studies conducted over the past quarter century increasingly point to a strong correlation between students achievement in K-12 science and mathematics and the teaching quality and level of knowledge of K-12 teachers of science and mathematics. (...). The CSMTP believes that these and others studies have clear implications for teacher preparation. Science and mathematics educators as well as practitioner have concluded that content knowledge must be a central focus of a science and mathematics teacher's preparation, (...)" (Executive Summary p 4).

-TPR Project (2001), *Teacher Preparation Research: Current Knowledge, Gaps and Recommendations* (Wilson et al 2001). This Research Report was prepared for the U. S. Department of Education. Center for the Study of Teaching and Policy (CTP), in collaboration with Michigan State University. As the authors say *"The purpose of this report is to summarize what rigorous, peer-reviewed research can and does tell us about key issues in teacher preparation"* (Executive Summary p i). For the review, the commission were asked to consider five questions posed by policy makers, educators, and the public. The first was formulated as:

"**Question 1:** *What kind of subject matter preparation, and how much of it, do prospective teachers need? Are there differences by grade level? Are there differences by subject area?* (p 4)

We will only focus on the results related to science. These results, as presented in the Executive Summary, are a little bit surprising, as the same authors note:

"It is no surprise that research shows a positive connection between teachers' preparation in their subject matter and their performance and impact in the classroom. Subject-specific methods

courses in education are useful too. But, contrary to the popular believe that more study in subject matter (e.g., through an academic major) is always better, there is some indication from research that teacher do acquire subject matter knowledge from various sources, including subject-specific academic coursework (some kind of subject-specific methods courses accomplish the goal)" (p i).

Illustrating the statement that "the more, the better" is not always true, the authors refer to a kind of *"threshold effect"* in teacher impact on student progress when compared with subject-specific coursework: In relation to physical sciences, an increasing positive relationship exists between the quantity of subject-matter academic coursework and student achievement; but when the number of courses are more than four, there is no more effectiveness in terms of student progress (p 8).

That an academic degree is not always indicative of better subject matter knowledge is also recognized in the *AETS Position Statement about Professional Knowledge Standards for Science Teacher Educators* (Lederman et al 1997). In describing the *"Standard 1: Knowledge of Science"*, the authors warns:

"The science teacher educator should have a particular area of expertise (represented by an academic degree or the equivalent)... We recognize, however, that an academic degree may not be indicative of the desired levels of subject matter knowledge" (p 2).

3.2.2 Teachers' knowledge and ontology

It seems obvious that the last two points of this section are related: teachers' conceptions are ingredients of teachers' subject matter knowledge. And it also seems clear that what makes reviewers demand a *"desired level of subject matter knowledge"* is a concern not just about "quantity" but about "quality" of knowledge.

To this respect, I would not say that teachers' conceptions deviated from academics' are in most cases due to lack (quantity) of subject matter knowledge (at least in the case of Secondary teachers). What I would say, based on my own experience as a science teacher educator, is that the teachers lack of critical thinking about the *nature of scientific entities* upon which science builds its law, models, and theories. As happened in the case of students:

From an ontological perspective, teachers' spontaneous conceptions are also a mere expression of an inadequate scientific ontology.

Epistemological analysis does not offer the level of details needed to make the nature of teachers' spontaneous concepts intelligible. The worry is that if we do not pay enough attention to this issue, we are on risk of repeating the same pattern followed when studying students' conceptions, and thus wasting our time instead of situating the problem in a deeper and more promising level.

3.2.3 Ontological analysis of teachers' spontaneous conceptions.

It could be said that research on ontological analysis of teachers' conceptions is at its very beginning. In our paper *Ontologies and Physics Teaching Training* (Gutierrez and Pinto 2001) we offered an example of how this analysis can be done. The paper was elaborated on the data taken from the STTIS Project. The sample consisted of 20 experienced Spanish secondary teachers, most of them graduates in physics or chemistry; they were volunteers to take part in the research project, in the section addressing to the implementation of curricular innovations in classrooms. The methods of gathering the data were interviewing and classrooms' observations. The teachers' spontaneous conceptions were related to energy degradation (full details in the quoted paper)

The results were as shown in Table 1.

Degradation of energy understood as	**Ontological beliefs**
- Opposite to energy conservation	- Energy conservation and energy degradation are considered as two principles that can not go together *[in closed systems energy is conserved; in open systems energy is degraded]*
- Energy transferred to the air	- The "place" where the energy is localised determines its quality *[if it is "in the air" then it is degraded]*
- Decrease of the amount of energy	- A change in quality is seen as a change in quantity *["each time there is less energy"]*
- Not related to internal energy	- A change in quality is viewed as in sensorial perception *[due to changes of temperature instead of increasing of U: "the pieces heat up"]*
- A change of the form of energy	- A change in quality is seen as a change in entity *["energy degradation means to change into another type of energy"]*
- Heating	- A process (heating) is considered as a state variable *["energy has been lost as heat"]*
- Energy dispersion	- Characteristic attribute of the concept is disregarded: no mention is made about capability of doing useful work *["dispersion is degeneration, degradation"]*

Table 1. Teachers' ontological beliefs about energy degradation (Gutierrez and Pinto 2001)

In the paper we concluded that teachers' ontological commitment acted as constraints that conditioned the interpretation of the proposed curricular innovation, and the way they taught the concept to their students.

In the recent reviewed literature, we have not found other studies related to teachers' spontaneous ontologies. We found only a paper from Taylor and Coll (2002), *Pre-service Primary Teachers ' Models of Kinetic Theory: an examination of three different cultural groups,* which offers some light to our purpose.

The study (according to the authors) was made within the mental model research framework, aiming to investigate Australian and Fijian preservice primary teachers' mental model for Kinetic Theory. The sample consists of 10 Australian and 24 Fijians, the components of the latter group being 12 indigenous Fijians, and 12 ethnic Indians. The method of gathering the data was interview about instances. The results, according to the authors, were as follows:

"This study showed that despite instruction in Kinetic Theory at secondary level, few of the pre-service primary teacher participants could apply this model effectively when explaining changes in materials. Furthermore, despite coming from three quite distinct cultural groups, the participants shared many alternative conceptions about physical science". (Conclusions, p 312).

There is no surprise in the contents of this conclusions; but the form of presenting them is a little surprising: as it happens quite frequently in literature related to "mental model" research[3], the data are given not as constituents of mental models, but as a description of "alternative conceptions",

[3] The polysemy of the term "mental model" and the consequent different approaches in research within the "mental model" framework are studied in Gutierrez 2002.

which has underneath a kind of “ontological flavour”. This “flavour” emerges on reading the paper, despite the fact that the authors never use the word “ontology”. As an example we quote the results obtained for the conceptions about the **change of states in matter** for Fijian teachers, reported as a summary in the Appendix of the paper, represented in Figure 1.

Alternative conceptions
A.2.1 Change of state associated with something other than temperature change (2)
"The humidity causes the ice cubes to melt."
A.2.2 Intermolecular spaces decrease from solids through liquids to gases (1)
"The particles tend to come together I mean sort of contract yes during melting they join together."
A.2.3 Condensation is due to leakage or attraction (6)
"most probably it (condensation) might have come through the glass."
A.2.4 Evaporation associated with absorption (5)
"...the liquid goes back to the sun...I think by (the sun's rays) absorbing it."
A.2.5 Particles viewed as living entities (1)
"I think the particles are living."
A.2.6 During evaporation different gas particles become bound together (1)
"here (during evaporation) it's a matter of air and the acetone being joined together, the particles bind together."
A.2.7 Condensation comes directly from ice (1)
"Maybe a little of it (condensation) comes from inside from the ice cubes here."
A.2.8 Evaporation occurs because heating makes the particles of a liquid lighter (1)
“When the particles of water is being heated up they tend to get light and rise up into the air.”

Figure 1. Fijian teachers’ conceptions about change of state of matter. From Taylor and Coll 2002, p 313. The numbers indicate the teachers holding that conceptions.

When reading the paper with intentional “ontological glasses”, we could highlight other interesting things: with a little arrangement, and adding some other quotations from the interview protocols transcribed on the paper (referred to in Table 2 with the teacher interviewed assigned number and smaller letters’ size), we can offer the following “ontological perspective” of the data shown in Figure 1:

Change of States of matter	Ontological beliefs
- Associated with something other than temperature change	-TEMPERATURE DOES NOT PLAY ROLE ON CHANGE STATES: [P1: They move far apart because eh...they get to the normal size, that means...it's far apart in the liquid form and when solid forms it gets together so that it has back to its normal size...] - *"The humidity causes the ice cubes to melt."*
- Intermolecular spaces decrease from solids through liquids to gases	THE PARTICLES CONTRACT DURING CHANGE STATES: - *"The particles tend to come together I mean sort of contract yes during melting they join together."*
- Particles viewed as living entities	-ANTHROPOMORPHIC VIEW OF PARTICLES' BEHAVIOUR: [P3: They (the water droplets in the surroundings) find it very suitable (to get to the sides of the glass), so they come in contact and they form water droplets] - *"I think the particles are living."*
- Condensation is due to leakage or attraction - Condensation comes directly from ice	CONDENSATION IS NOT RELATED TO WATER VAPOUR IN THE ATMOSPHERE: [P13: Maybe when the air particles get below a certain temperature they change their form] - *"most probably it (condensation) might have come through the glass."* - *"Maybe a little of it (condensation) comes from inside from the ice cubes here."*
- Evaporation associated with absorption - During evaporation different gas particles become bound together - Evaporation occurs because heating makes the particles of a liquid lighter	EVAPORATION NOT RELATED TO ENERGY OF PARTICLES: - *"...the liquid goes back to the sun...I think by (the sun's rays) absorbing it."* - *"here (during evaporation) it's a matter of air and the acetone being joined together, the particles bind together."* -*"When the particles of water is being heated up they tend to get light and rise up into the air."*

Table 2. Fijian teachers' ontological beliefs about change of state, according to data from Taylor and Coll 2002. Headings in capital letters added.

As we can observe, ontological analysis at this stage is only a meta-analysis or second order analysis of the described teachers' spontaneous conceptions. What will (hopefully) follow is the modelling of teachers' spontaneous conceptions in a set of related and dynamic constituents conforming an intelligible and explicative model of teachers' spontaneous thinking.

4. CONCLUSIONS. TEACHER EDUCATION, EPISTEMOLOGY AND ONTOLOGY

In revising the literature, we observe that the conceptualisation of Teacher Education programs is far from representing something consolidated. As Cochran and Jones (1998) pointed out *"There is a lack of consensus about ideal teacher education programs in general or ideal science teacher education in particular" (*p 712). According to different interests or detected necessities, authors propose several contents as fundamental for teacher education programs (i.e. Bell 1998, Mumby y Russell 1998, TPR Project -Wilson et al 2001). If we look at the themes enunciated in the different proposals, and put them together, the result could be listed as below:

-Learning some important concepts of Science

-Learning about Teaching and Learning

-Curriculum Development work

-Practicing and evaluating new teachers strategies

-Developing their own ideas about Teaching and Learning

-Teachers' prior ideas about Science and Science Education

-Epistemology of Science

-Socially-reconstructed knowledge of what it means to be a teacher of science

We could say that epistemology is a subject in which consensus had been accomplished. The long tradition in studying this theme and its consequences for teaching and learning, have contributed to this consolidation as a fundamental component in science teacher education. But ontology is still totally absent from the mind of the designers of the different proposals.

The status of teachers' spontaneous conceptions seems to be interpreted in literature as almost exclusively coming from a lack of subject matter knowledge. And possibly this may be one of the factors. But taking into account the academic preparation of teachers in their own subject matter (at least in the case of Secondary teachers), other factors must exist to explain the phenomenon. In our view, one of these factors is related to the ontological understanding of scientific and of commonsense entities.

Scientific ontology consists of scientific concepts or entities formally constructed by a scientific community, and it acquires sense from scientific models or theories to which they refer; spontaneous ontology consists of entities related to the world, spontaneously constructed, and they have meaning if they are able to give account of the state of the world. Both conform two incommensurable (Kuhn) universes of understandings. Teachers need critical knowledge about these two sets of entities in order to differentiate them and to be capable of adequately managing the "rule of games" (Wittgenstein) or the "precise language" to refer to one or the other.

The academic background of a graduated teacher is usually rooted within the "normal science" (Kuhn) framework; thus, in these circumstances there is no room for any kind of critical knowledge. Our proposal is that

Ontological study should be introduced in teacher education, as a powerful way to acquire the necessary critical thinking about the nature of the entities (their universe of meaning) which they are managing in their teaching.

The introduction of ontology in teacher education could have several advantages:

- Facing the teachers with their own conceptualisations, be they academics or unorthodox. It will be expected that with one adequate methodology (reflection, discussion, distinction), teachers will acquire the needed critical thinking.

- This critical thinking will make teachers aware of the importance of language (the universe of meaning they are referring to) when teaching scientific concepts to students.

- The ontological background could enlighten teachers with better knowledge of the status of students spontaneous thinking, thus, facilitating the putting into practice new methods of teaching adequate to such status.

With so little data on teacher education in this area, this proposal and its possible advantages are necessarily open to discussion. But we find here a fascinating field of research, plenty of possibilities for bringing about more effective science teacher education.

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