POTENTIALLY MEANINGFUL TEACHING UNITS - PMTUS
(Unidades de Ensino Potencialmente Significativas –UEPSs)[1]

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Abstract

The construction of a didactic sequence is proposed based on learning theories, specially the meaningful learning one. Assuming that there is no teaching without learning, and that teaching is a means while learning is the goal, a sequence is proposed as a Potentially Meaningful Teaching Unit (PMTU). Steps for its construction are suggested, examples are given, and a glossary of technical terms involved is provided.
Keywords: teaching unit; meaningful learning; potentially meaningful teaching.

Resumo

É proposta a construção de uma sequência didática fundamentada em teorias de aprendizagem, particularmente a da aprendizagem significativa. Partindo das premissas de que não há ensino sem aprendizagem, de que o ensino é o meio e a aprendizagem é o fim, essa sequência é proposta como sendo uma Unidade de Ensino Potencialmente Significativa (UEPS). São sugeridos passos para sua construção, são dados exemplos e é apresentado um glossário dos termos técnicos utilizados.
Palavras-chave: unidade de ensino, aprendizagem significativa, ensino potencialmente significativo.

Introduction

Teachers in school, it does not matter whether at elementary, high school or college level, present students knowledge they are supposed to master. Students copy such knowledge chunks as a kind of information to be learnt by heart, reproduced in evaluative situations, and quickly forgotten afterwards. This represents the classic model of teaching and learning, which is grounded in the teacher's narrative and in the student's rote learning.

Learning theories suggest different approaches, as well as research findings of basic research on teaching. However, neither the theories nor these findings. do not reach the classrooms. It is not the case here to blame educational psychologists, educators, researchers, teachers, and students, however, it is a fact that the narrative model is accepted by everybody—students, teachers, parents, and society in general—as "the model" for teaching and that rote learning is "the learning model". Actually, as far as practice goes, it is an enormous loss of time.

This paper intends to contribute to change, at least partially, this situation by proposing the construction of Potentially Meaningful Teaching Units, which constitute teaching sequences theoretically based aiming at meaningful learning—not rote/mechanical learning—and that can favor applied research on teaching, that one directed to real classroom practices.

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Constructing Potentially Meaningful Teaching Units - PMTUS

Goal: Such a constructing process aims at developing potentially meaningful teaching units to facilitate the occurrence of meaningful learning of specific declarative and/or procedural knowledge topics.

Philosophy: Teaching can only happens when learning occurs, and learning has to be meaningful; teaching is the means and meaningful learning is the end to be reached; teaching materials that aim at this type of learning and have to be potentially meaningful.

Theoretical Framework: It comprises the theory of meaningful learning of David Ausubel (1968, 2000), in classical and contemporary perspectives (Moreira, 2000, 2005, 2006; Moreira and Masini, 1982, 2006; Masini and Moreira, 2008; Valadares and Moreira, 2009), educating theories of Joseph D. Novak (1977) and D.B. Gowin (1981), social interactional theory of Lev Vygotsky (1987), conceptual fields theory of Gérard Vergnaud (1990; Moreira, 2004), mental models theory of Philip Johnson-Laird (1983), and the critical meaningful learning theory of M.A. Moreira (2005).

Principles:

- Prior knowledge is the variable that most influences meaningful learning (Ausubel);
- Thoughts, feelings, and actions are integrated in the learner, and this integration is positive and constructive, when learning is meaningful (Novak);
- It is the learner's responsibility to decide to meaningfully learn a given knowledge chunk (Ausubel; Gowin);
- Advance organizers display/ show relatedness between new knowledge and prior knowledge (Ausubel; Moreira);
- Problem-situations add meaning to new knowledge (Vergnaud) and they should be developed to raise the/arise in the students the intentionality to learn meaningfully;
- Problem-situations can work as advance organizers;
- Problem-situations should be proposed in increasing complexity levels (Vergnaud);
- When facing a new/novel situation, the first step to solve it is to construct in the working memory a functional mental model that is structurally analogous to the given situation (Johnson-Laird);
- Progressive differentiation, integrative reconciliation, and consolidation should be considered when organizing teaching (Ausubel);
- Meaningful learning evaluation should happen as a search for evidences;
- Meaningful learning is progressive;
- The teacher's role is to provide carefully selected problem-situations, to organize his/her teaching, and to mediate the students' grasping of meanings (Vergnaud; Gowin);
- Language and social interaction are crucial to the grasping of meanings (Vygotsky; Gowin);
- A teaching event involves a triadic relation among student, teacher, and teaching/educational materials aiming at leading the student to grasp and share meanings that are accepted in/ acknowledged by in the context of a given teaching subject/discipline/ knowledge area (Gowin);
- This relation can also be quadratic when the computer is used as a learning mediator, and not just as an educational material;
- Learning should be meaningful as well as critical, and not mechanical (Moreira);
- Critical meaningful learning is motivated/ favored by the search for answers (questioning), through the use of a diversity of materials and teaching strategies, and by disclaiming the narrative mode/model in favor of a student-centered teaching, instead of focusing on the memorization of already known answers (Moreira).

Sequential Aspects (steps):

1. Define the topic to be approached by identifying the declarative and procedural aspects as accepted in the context of the teaching subject in which this topic is inserted.

2. Develop/Propose situation(s) – discussion, questionnaire, concept map, problem-situation(s) – that lead the student to express/ externalize his/her prior knowledge, independently of being, or not, accepted within the context of the teaching subject that should be relevant to the meaningful learning of the topic (goal/objective) on the agenda/that is being undertaken.

3. Propose introductory level problem-situations that consider the student ' s prior knowledge so as to prepare him/her to the introduction of the knowledge items (declarative or procedural) to be taught; these problem-situations might involve, from the very beginning, the topic on the agenda though not with the goal of starting to teach it; such problem-situations should serve as advance organizers; these situations give/add meaning to the new knowledge, but, in order to achieve this, the student should perceive them as problems and should be able to mentally model them ; mental models are functional to the learner and result from his/her perception and prior knowledge (invariant operators); these first/initial problem-situations can be proposed with/through computational simulations, demonstrations, videos, life problems, representations brought about by the media, classical problems from the subject matter, but they have always to be in the format of an accessible and problem generating mode, that is, never just as an exercise of a routine application of an algorithm.

4. Once initial situations have been developed/carried out, introduce/present what is to be taught/learned, taking into consideration the features of progressive differentiation, that is, starting from the most general and inclusive aspects to offer/provide an introductory/initial view of the whole, which means presenting a panorama of the most important elements/features of the teaching unit, but immediately followed by offering examples and approaching quite specific aspects; teaching strategy might be, for instance, a short lecture followed by a small group collaborative activity, which, in turn, can be followed by a presentation or discussion activity by the large group;

5. Next, the most general and structuring aspects (that is, what is intended to be taught) of the teaching unit content should be resumed with a new presentation (it can be another short oral lecture, a text, or the use of a computational resource), though, in a higher complexity level in relation to the first presentation; problem-situations should be proposed in an increasing level of complexity; new examples should be given, emphasizing differences and similarities in relation to situations and examples already presented , that is, promoting integrative reconciliation; after this second presentation, a collaborative activity aiming at the students' social interaction, negotiation of meanings, with the teacher as mediator, should be proposed; such an activity might be problem solving, construction of a concept map or a V diagram, a lab experiment, a small project, however, it has to involve negotiation of meanings and teacher mediation;

6. To conclude the unit, the process of progressive differentiation should be continued, resuming the most relevant features of the given content, though under an integrative perspective, that is, aiming at integrative reconciliation; this should be carried out through a new presentation of meanings in a brief oral lecture, the reading of a text, the use of a computational resource or an audio-visual program; what matters here is not the strategy itself, but the way to handle/deal with the unit content; after this third presentation, new problem-situations should be solved at a higher complexity level than the previous ones; these situations should be solved in collaborative activities

that afterwards will be presented and/or discussed in the large group with the mediation of the teacher;

7. Learning evaluation according to PMTUs should occur along their implementation, recording everything that might be considered as evidence of the occurrence of meaningful learning of the content handled in class; furthermore, there should be a an individual summative evaluation after the sixth step, in which questions/situations implying understanding, grasping of meanings, and, ideally, a transferring skill should be proposed; such questions/situations should be previously validated by professors with expertise in the given teaching subject; performance evaluation of the PMTUs student should be equally based both on the formative evaluation (situations, task collaboratively solved, teachers' records) and on the summative one;

8. A PMTU will only be considered successful when the students' performance evaluation can provide evidences of meaningful learning (grasping of meanings, understanding, explaining skills, competence in applying his/her knowledge to solve problem-situations). Meaningful learning is progressive and mastery of a conceptual field is also progressive, thus, the emphasis on evidences, and not on end-behaviors.

Transversal aspects:

- Throughout the steps, teaching materials and strategies have to be diversified, questioning has to be privileged en relation to ready-made answers, and dialogue together with critique should be favored/stimulated;
- As a learning task, in activities developed along the PMTUs, students might be asked to propose their own problem-situations in relation to a given topic;
- Although the PMTU should emphasize collaborative activities, it can also include instances of individual activities.

Diagrams: In order to approach in a diverse way the structure of a PMTU and to use diagrams, which can be useful in the proposed collaborative activities, two different types of diagrams are presented here.

V diagram

Figure 1 shows a V diagram (Gowin, 1981) to streamline the construction process of a Potentially Meaningful Teaching Unit.

Concept map

Figure 2 presents a concept map to represent in another way the construction of a Potentially Meaningful Teaching Unit.

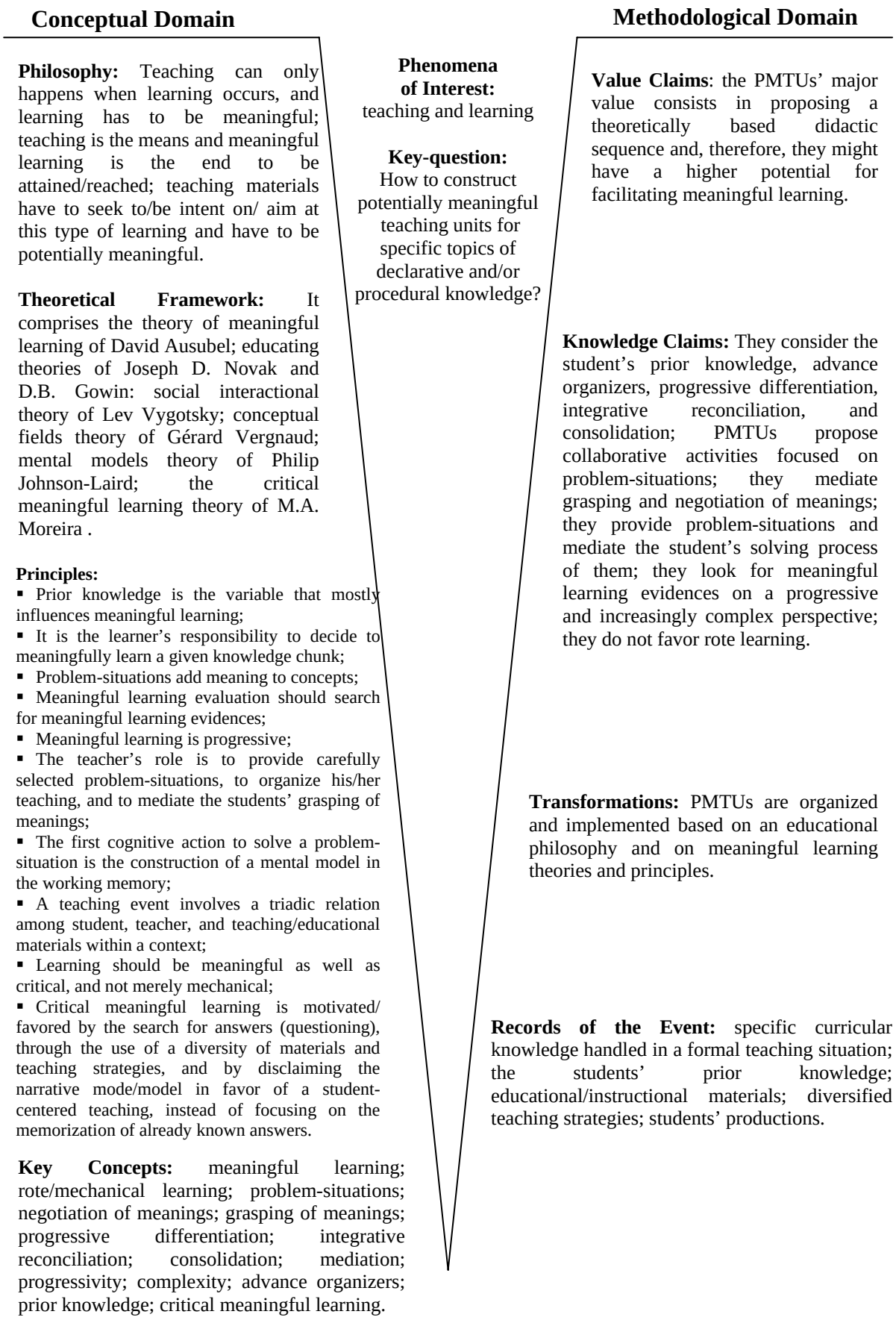

Figure 1. A V diagram for constructing a PMTU.

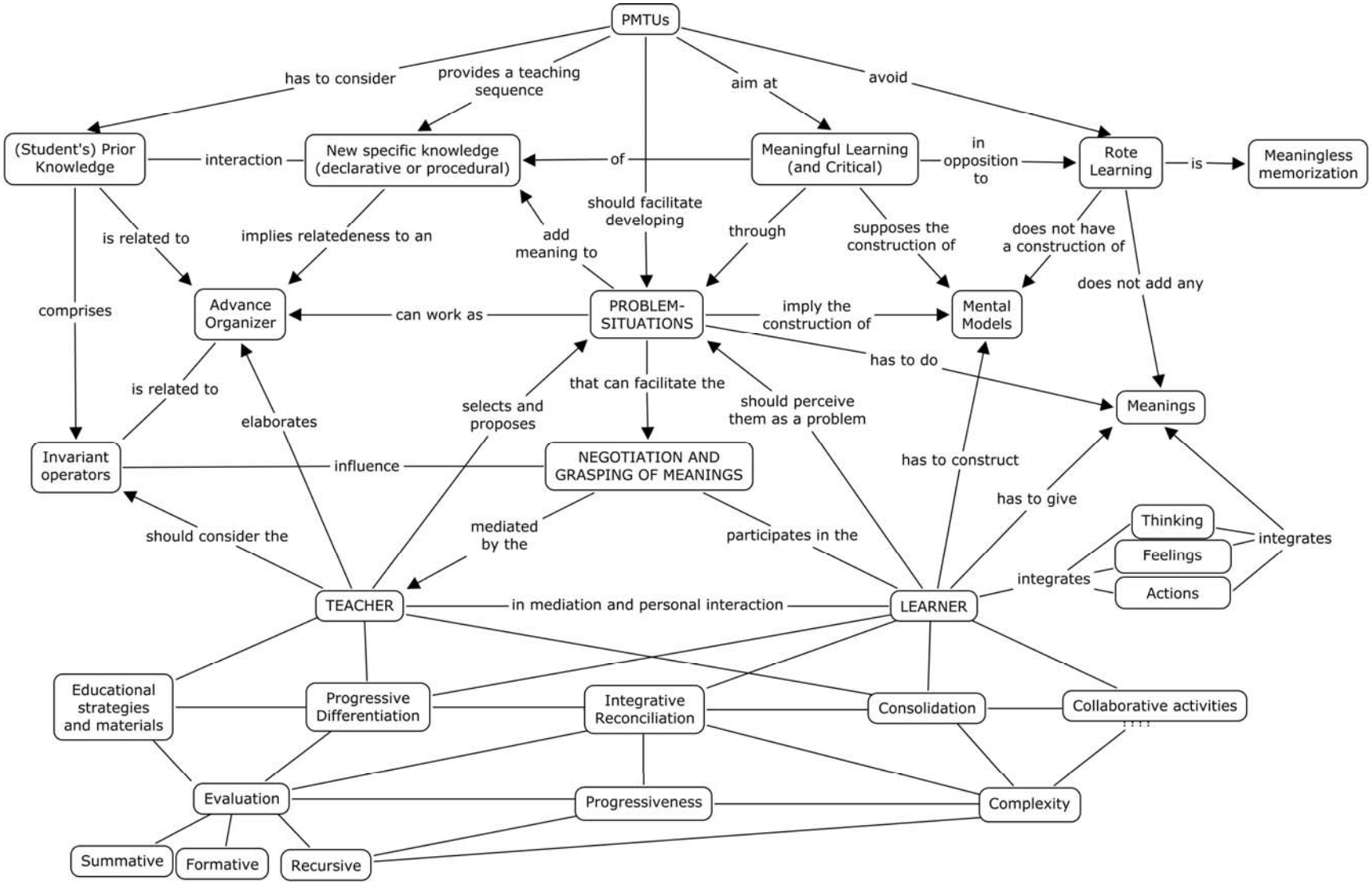

Figure 2. A concept map for the construction of a PMTU. Connecting propositions were not added to the lower part of the map to avoid density. Arrows were used only to facilitate reading. It is important not to misinterpret a concept map with a flow diagram. A concept map is structural; it is not sequential.

Glossary

Meaningful learning: it is learning with meaning, comprehension, ability/skill to explain and to apply the constructed/acquired knowledge to new situations; it is a result of the non-arbitrary and non-literal interaction between prior knowledge and new knowledge; basically, it depends on prior knowledge, which enables the learner to grasp meanings (on an interactionist, dialectic, and progressive perspective) from new knowledge and on the learner's intentionality/ willingness to grasp those meanings.

Critical Meaningful Learning: it is a perspective that allows the individual/subject to be part of his/her own culture, while, at the same time, to be out of it. Through this type of learning the individual/ subject can integrate his/her culture without being oppressed by this same culture, its rituals, myths, and ideologies. This type of learning will enable him/her to handle in a constructive way with change, but without letting it dominate him/her. Thus, the individual will be able to deal uncertainty, relativity, non-causality, probability, and the non-dichotomization of differences (Moreira, 2005).

Rote learning: it is meaningless memorization of short-term information, that is, to learn by rote is to learn by heart, verbatim. Cognitively speaking, information is internalized without practically any interaction with prior knowledge. According to school jargon it is called "parroting".

Collaborative activity: it implies task resolution (problems, concept maps, model construction, carrying out a lab experiment) in small groups (from two to four participants, in which all members participate and present its results/findings and product to the large group; this result/these findings should be attained as the small group consensus that will be critically received/ acknowledged by the large group.

Formative evaluation: it constitutes an evaluation of the student's progress along a stage of his/her learning; it contributes to the regulation of the ongoing learning process in it progressive mastery of a conceptual field; it is a continuous evaluation process that emphasizes the meanings presented by the student as well as his/her grasping process.

Summative evaluation: it aims at evaluating the scope of some given learning objectives at the end of a learning stage; it is usually based on end-of-the unit exams and on the finals.

Grasping of meanings: knowledge (concepts, propositions, constructs) of a given teaching subject have meanings that are accepted in the context of such a subject matter and are shared by a community of users; to learn it meaningfully, the student first has to grasp these meanings so as to decide to incorporate them to his/her cognitive structure substantively and non-arbitrarily; Gowin(1981) states that this grasping of meanings is prior, and at the same time a condition, to meaningful learning.

Declarative knowledge: it comprises that knowledge that can be verbalized or expressed, in one way or another, and it refers to knowledge about objects and events; it is mentally represented by propositions and mental images/imaging.

Prior knowledge: it includes subsuming concepts, representations, schemas, models, personal constructs, alternative conceptions (misconceptions), invariant operators, that is, cognition processes that are already present in the learner's cognitive structure.

Procedural knowledge: it comprises cognitive abilities involved in knowing how to do something; it is knowledge on how to perform actions; it might be mentally represented by/in production, that is, norms/rules for conditions and actions.

Consolidation: it stands as one of the programmatic Ausubelian principles for content/subject matter (together with progressive differentiation, integrative reconciliation, and sequential organization), according to which it is necessary to emphasize domain or mastery of what is being studied, before new materials are introduced, so as to guarantee readiness for the teaching subject and success in the sequentially organized learning. However, this principle has to be compatible with the progressiveness of meaningful learning, as well as with progressive differentiation and integrative reconciliation.

V Diagram: it is a heuristic instrument, developed by D.B. Gowin (1981) to facilitate comprehension of the knowledge construction process; for this reason it is called epistemological Vee. At the center part of the Vee, there is the key question, which is the basic question to the knowledge construction process; at the left side, there is the conceptual (concepts, principles, theories, philosophy) and at the right side appears the methodological domain (records, data, methodological transformations, attempts to answer the basic question). Simplifying it, it is possible to say that the left side of the Vee corresponds to thinking, while the right side to acting or doing; knowledge production results from the interaction between a conceptual domain (thinking) and a methodological one (doing or acting). At the tip of the Vee, it is appears the event or the object of study out of which records are made and, when these are methodologically transformed, they generate knowledge claims (answers) about which value claims are made.

Progressive Differentiation: It means, as a teaching subject programmatic principle that ideas, concepts, more general and inclusive content propositions should be presented at the very start of the teaching event and be progressively differentiated along this process, in terms of details and specificities. From a cognitive perspective, it is what happens with a given subsumer, when it anchors new knowledge in an interactive and dialectic process.

Operator invariants: these are the knowledge chunks comprised by/included in the schemas. Schema is the behavior organization for a given class of situations/some types of situation. There two types of operator invariants that are the major schema components: theorems-in-action and concepts-in-action. Theorem-in-action is a proposition that is held as true about what is real/ about reality. Concepts-in-action is a predicate, that is, a thought category held as pertinent and relevant to a given situation (Vergnaud, 1990).

Concept Map: it is a hierarchic diagram of concepts and relations between/among concepts; hierarchic means that in such a diagram it is somehow possible to notice that some concepts are more relevant, inclusive, comprehensive, and more structured that others; this hierarchy does not have to be necessarily vertical, from top to bottom, although it is used very much this way. In a concept map, relations between/among concepts are indicated with connecting lines; on these lines, words or sentences are written to explicit the type of relation that exists between / among the concepts; these words can be verbs and are connectors or connecting words. The two or more concepts plus the connective form a proposition in a synthetic language. A concept map aims at representing the conceptual structure of the content that is being diagrammed. However, it is important not to confuse it with a flow diagram, a synoptic table, mind map, and other kinds of diagrams.

Mind Map: it is freely "irradiated" thought triggered by a central image, or by a keyword, as if they were ramifications (branches); less relevant topics are also represented as branches that are linked to others of a higher level of importance; these branches form a connected nodal structure (Buzan and

Buzan, 1994; Ontoria et al., 2004). A mind map uses totally free associations, whereas, a concept map the only accepted ones are those of the teaching subject context.

Potentially Meaningful Material: meaning resides in the persons, not in things. Therefore, there is no such a thing as a meaningful book or a meaningful class/lesson, but educational/instructional materials, in general, can be potentially meaningful; thus, they must have a logical meaning (have a structure, organization, examples, adequate language, that is, to be learnable) and the subjects must have enough/ requisite/adequate prior knowledge to add meaning to knowledge that is being brought up by such materials/conveyed by these/such materials.

Working Memory: it is the cognitive system that allows the individual to keep active an amount of limited information (7 + 2 items) for a short period of time. Earlier, before the beginning of the cognitive revolution of the 50s, it was called short-term memory. Today, it is presumed its major role to be the temporary storage of intermediate mental computational results, when problem solving occurs (Wilson and Keil, 2001).

Mental Model: it is a structural analogous of the state of things in the world, which the individual constructs in his/her working memory. When facing a new situation, the individual's assimilation schemas do not work, so, he/she constructs in his/her mind a functional and recursive model for this situation that will have its analogous structure. He/She produces inferences and, depending on the effectiveness of such inferences, he/she recursively modifies the model, which at this time, can be even discarded. Contingent on the consecutive need to face same class situations, the mental model can stabilize or it can evolve to an assimilation schema.

Negotiation of Meanings: actually, it is not a real negotiation, since it is an exchange and an externalization of meanings: the teacher, who masters the meanings that are accepted in the teaching subject context, presents them to the student. He/She has to externalize to the teacher how he/she is grasping such meanings. If this grasping of accepted meanings does not occur, the teacher has to present them in a new way, and the student has to externalize them again. This can happen many times until the learner is able to negotiate them the way they are accepted in the context of the teaching subject. This is what is meant by negotiation of meanings. It might be a long process in which the teacher mediates the grasping of meanings by the student.

Advance Organizer: it is the introductory instructional/educational material presented to the student prior to being learned by the student in a higher level of abstraction, generality, and inclusiveness; according to Ausubel (1968, 2000), its main role is that of serving as a bridge between what the learner already knows and what he/she should know in order to learn it meaningfully. In classroom practice, advance organizers work better when they explicit a relatedness between new knowledge and what already exists in the learner's cognitive structure. The learner often has this prior knowledge but he/she is unable to perceive it is related to the one being presented to him/her.

Integrative reconciliation: it is, from an educational/instructional perspective, a programmatic principle of the teaching subject, according to which teaching should explore relations that exist between/among ideas, concepts, and propositions and it should point out important similarities and differences between/among them, thus, reconciling real or apparent discrepancies. Cognitively, along what is being newly learned, knowledge that has been already established in the learner's cognitive structure can be acknowledged as related, be reorganized, and get new meanings. This recombining of prior existing elements in the cognitive structure is integrative reconciliation under the view of cognitive organization.

Recursiveness: it is the possibility of redoing the learning tasks; it comprises the use of error as a source of learning. Mental models, for instance are recursive. The subject, when facing a new

situation, constructs a working mental model to enable him/her to face this situation. If this model does not work, the subject goes on recursively modifying it until it satisfies him/her Concept maps, for example, can be recursively modified: the learner constructs his/her first map and shows it to the teacher and/or to his/her peers. This results in comments, suggestions, and criticism that the learner takes into consideration to redo the map and to present it once more to teacher and/or peers, and this process goes on recursively.

*Meaning: a*ccording Vygotsky (1987), meaning is the sum of psychological events that a word or a situation evokes in consciousness; it is a fluid and dynamic whole that has variable stability zones, of which the most stable and precise is meaning; Meaning is a social construct/construction that has a conventional origin and is relatively stable, but it is mutable and contextual. Whereas sense is personal, meaning is social.

Problem-situation: it implies a task, which not necessarily is an end-of-chapter problem; it might be an explanation of a phenomenon with an apparent contradiction, the construction of a diagram, or any other from a broad range of possibilities, however, independently of the type of task, it is essential that the student perceive it as a problem. Thus, it is worthless to "propose" a problem the student perceives as an exercise on the application of a given formula. Problem-situation and conceptualization have between them a dialectic relation: the situations add/give meaning to concepts, but as the student constructs concepts, he/she becomes increasingly able to successfully face progressively more complex new situations. When teaching, situations should be proposed/suggested in increasing levels of complexity, though a degree of mastery within a given complexity level is important before going on to the next level. In this, the concept of conceptual field proposed by Vergnaud (1990) is implicit as a field of problem-situations, whose mastery is progressive and slow, and has ruptures as well as continuities.

Subsumer: it corresponds, in English, to what Ausubel explained as the kind of prior knowledge that can include or absorb new knowledge in something already known; it means "take", "absorb", "accept", "include", and "usher in". Subsumption is the process of subsuming (under). It should be noticed that in meaningful learning, subsumption implies an interactive process, that is, both the subsumer and what is being subsumed (under) modify themselves in relation to meaning.

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ANNEXES: PMTUs

ANNEX 1

PROPOSAL OF PMTUs FOR TEACHING THE STANDARD MODEL OF PARTCLE PHYSICS

M.A.Moreira*

Objective: to teach the Standard Model of Elementary Particles in High School

Sequence:

1. *Initial situation:* to build with the students a concept map about the subject matter; firstly, ask students what constitutes this subject matter while writing on the chalk board what they are saying; next, mark the words students point out those they believe to be the most relevant ones, then, place them in a hierarchic diagram (concept map); finally, ask each student to explain, in writing, with their own words, the map that was constructed in group; this individual explanation should be handed to the teacher at the end of this initial activity, which happens in the first class/meeting of this PMTU.

2. *Problem-Situations:* Examples a) if the nucleus of the atom is made of positively charged particles (protons), why doesn't explode?; b) if negative and positive electric charges are attracted to one another, why aren't the electrons absorbed by the nucleus? ; c) If electrons and protons have mass, what is the role of gravitational interaction in the atom stability? ; d) What is the role of neurons in the structure of the atom? e) Would it make any sense to think that basic atomic particles (electrons, protons, and neutrons) could be made for other even more elementary particles? These situations proposed here, which are based on the type of knowledge students have explicited in the prior class, should be discussed in the large group with teacher mediation and not necessarily should come to answers to the proposed problems.
As a next action, individual copies of the article Partículas e interações (Moreira, M.A., 2004, Física na Escola, v.5, n.2, pp.10-14), should be distributed among the students that should be given some time to read it and, after reading it, gather together in small groups (two to four participants) to build a table that should be analogous to Table 1, in the article, though simplified. After finishing this task, groups exchange their tables and each group corrects, comments and suggests changes in the other group's table. When each group gets back its table, it can modify it and hand the teacher this final version. This PMTU will take two to three classes/meetings.

3. *Revision/review:* the class can start with a review/revision that can be a mini lecture class/lesson on what has already been handled up to that point about the constitution of/what the subject matter comprises, so as to open up room for the students' questions. Next, a 20 to 30 minute video on Elementary Particles (e.g., v. BBC. The. Big. Bang. Machine. MVGroup) is presented. After the video presentation, the following articles are distributed among the students Um mapa conceitual para partículas elementares (Moreira, M.A., 1989, Revista Brasileira de Ensino de Física, v.11, pp. 114-129) and Um mapa conceitual para interações fundamentais (Moreira, M.A., 1990, Enseñanza de las Ciencias, v.8, n.2, pp.133-139) , students are, the, asked to read them and, in small groups, they draw a concept map of elementary particles and fundamental interactions, that is, a map that integrates, on a simplified way, the two maps presented in the articles. Al least some of these

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concept maps are to be present to the large group (in Power Point, on the chalk board, posters, or banners of paper and markers). Each group maps should be handed in to the teacher, who will revise them and give them back to the students the next class, and the students, as they wish, can modify them to come up with their final version of their map. This activity will take two or three classes.

4. *New problem-situation at a higher complexity level:* to construct a V diagram of the Standard Model; to present a brief initial lecture with examples about what a V diagram is and on what constitutes its proposal, that is, what its role is; emphasize its epistemological nature; next, to distribute among students copies of the article Um Vê epistemológico para a Física de Partículas (Moreira, M.A., 2010, Revista Chilena de Educación Científica, 9(1): 24-30), and ask students to construct, in small groups, a V diagram to the Standard Model, with the following basic question "How does the Standard Model of Elementary Particles show that Physics is a human construct/construction and that all scientific knowledge is constructed? ". Some of these diagrams should be presented to the large groups for discussion, and all of them should be handed in to the teacher for a qualitative analysis; as a result of this evaluation, the students can, is they want, reconstruct these diagrams. This activity will take two or three classes.

5. *Individual Summative Evaluation:* this activity that will take one class will have already been proposed to the students, thus, it will not come to them as a surprise; it proposes open questions in which the students can freely express their own understanding of the Standard Model; ask questions, propose/demand a schematic representation or diagram that can show evidences of meaningful learning; it should be avoided any evaluation instrument based on "right or wrong" answers.

6. *Final Integrative Dialogic Lecture Class:* at this point, it is time to retake the total content of the PMTUs, review the maps and the V diagram based on the articles studies in the previous classes; it should be called attention to descriptive and explanatory potential of the Standard Model in its relation to the constitution of matter; difficulties that were overcome by this theory, confirmed previsions, as ell as still existing difficulties that can lead to changes or to its disclaim in favor of other better explaining one.

7. *Learning Evaluation in the PMTUs*: it should be based on what the students have produced, on classroom observations, and on the individual summative evaluation, whose weight/value should not be more than 50%.

8. *Evaluation of the PMTU itself:* It should be happen in relation to the obtained learning results; then, some activities should be reformulated, if necessary.

Total class-hours: 9 to 12

ANNEX 2

PROPOSAL OF PMTUs FOR TEACHING TOPICS OF QUANTUM MECHANICS

Adriane Griebeler*

Objective: to facilitate the grasping of meanings of basic concepts in Quantum Mechanics in High School—quantization, uncertainty, quantum object, state, state superposition.

Sequence:

1. *Initial situation:* students are motivated to develop a mental map for Quantum Physics (QF). In this map, they are free to establish associations among their knowledge chunks, representations, and cognitive actions based on a key word or on a central image. So, students feel at ease to establish relations between QF and other areas of Physics or/and their daily life and/or their social representations. Maps should be handed in to the teacher. In order to think about the given topic, students receive the lyrics and listen to the song Quanta, by Gilberto Gil. This activity will take one class.

Initial Problem-situations:

a) What have you read, heard, or seen about Quantum Physics?
b) Where is QF applied? What does QP study?
c) How does QP differ from the other areas of Physics (Mechanics, Thermodynamics, Electromagnetism, etc.)?
d) What is a quantum of matter? And a quantum of energy?
e) What is your opinion about the following adds/ headlines/titles (Magazine cut-outs or sites that talk about "Quantum therapies" brought by the teacher)
f) Have you ever had any type of contact with the type of therapy that some call "quantum"?

These questions/situations should be discussed in the large group with the teacher as mediator, aiming at listening to the stands of the whole group and at stimulating/favoring interest on this subject, with no need to get to a final answer.

Next, an individual copy of the text Física Quântica para Todos (partially adapted from Nunes, A. L., 2007, Física Quântica para Todos, XVII SNEF.), available in the teaching support materials organized by the teacher. Students are given some time to read it, then they gather together in small groups to discuss it, and, afterwards, they can either sum it up, or create a diagram, or a drawing collaboratively. Products of this activity are handed to the teacher that will evaluate them qualitatively and will hand them back to allow students to redo their work considering the feedback comments they have received. This stage will take three classes.

2. *Growing/Deepening/Strengthening knowledge:* Concepts of quantization, quantum object, uncertainty, state, and superposition of states are handled here. These contents are presented in texts and slides, as large group discussions are favored. At the end of the introduction of these new contents, the cut-outs and adds are presented again to question students on the validity of what such material propose, as well as their views on up to what extension these appropriations are legitimized by Physics. This stage takes three classes.

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3. *New situation:* these concepts are presented again as a video, Mecânica Quântica produced by Discovery and accessed at <http://www.youtube.com/watch?v=pCgR6kns5Mc>. Next, students, in small groups, are asked to construct a concept map for Quantum Mechanics. Beforehand, there is a brief introductory lecture on how to build a concept map followed by some examples of it. Then, maps are constructed and exchanged among the groups to have them compared and to get peer suggestions. Some of them are presented to the large group. All maps are handed in to the teacher for evaluation. They will be qualitatively evaluated and, then, returned to the students that might reformulate them and hand them back to the teacher. This activity takes three classes.

4. *Comparing maps:* in the following class, there will be an activity involving the mind maps developed in the first class and the concept maps drawn the class before. A qualitative comparison between these two types of maps aiming at looking for aspects comprising alternative conceptions (misconceptions), or social representations, about Quantum Physics, which might have been presented in the mind maps of the first class and which might lack/be absent in the concept maps. Such an aspect will be used to approach the subject again and to explain to the students that Quantum Physics cannot be used as a scientific foundation for topics those advertisements presented.

5. *Progressively differentiating:* new problem-situations will be presented in relation to the concepts of quantization, quantum object, uncertainty, state, and superposition of states, mostly as images such as, for instance, the one of the Schröedinger Cat, which is available at http://averomundo-jcm.blogspot.com/2009/10/gatos-e-virus.html , and the development of a classroom newspaper will start with small articles, comic strips, and/or images on the studies topics. The teacher will mediate this newspaper development that, when finished, will be exhibited in school and available to the whole school community for reading. This activity will take three classes.

6. *Individual evaluation:* individual evaluation will comprise open questions involving the key-concepts of the given unit. This activity will take one class.

7. *Final class and evaluation of the PMTU in the classroom:* this activity involves the analysis of the answers to the proposed questions of the individual evaluation. It will also include final integrating comments on the approached content. There is also an oral evaluation by the students about the teaching strategies that have been used and about their own learning. This activity will take one class. Students' comments will be recorded, if they comply with it. .

8. *Evaluation of the PMTU:* aiming at this, there will be a qualitative analysis by the teacher of the evidences he/she has, or not, perceived that might point out to the meaningful learning of the unit key concepts, both in the individual evaluation as in the participant observation, as well as in the classroom evaluation of the PMTU by the students at their last meeting.

9. Total class-hours: 16

ANNEX 3

A PMTU PROPOSED FOR TEACHING BASIC IMMUNOLOGY

Viviane A. Andrade*

Context: this teaching unit was planned and developed directed at a 40-hour (12 class meetings) extension course on Basic Immunology, which was offered to students enrolled in a Technical High School Course on Nursing.

Objective: to teach Basic Immunology (Anatomy and Physiology of the Immune System), based on homeostasis, one of Biology most central ideas, according to Novak (1970).

1. *Initial Activities (2 class-meetings):* to suggest teaching situations that favor a broad inventory/ log of the students' prior knowledge. Before the topic/theme presentation, the development of three initial activities is suggested: a comprehensive/broad introductory question/issue about the topics students expect to learn; issues/questions related to the topic (How does the Immune System work/function in the human organism context? What words or phrases do you relate to the topic? Can you identify two instances/situations in which the Immune System will act upon your organism?) to be individually answered without using/resorting to any reference source; oral and collective discussion that is guided by the questions and the previously answered questions.
Next, students should present a brief report on the history of Immunology and its context of the development in the western world, emphasizing knowledge construction process. Afterwards, a discussion is proposed for the following question " Does man nowadays develop smallpox ?" After the students have shared an answer to this question, a synthesis/ summary of the article by Lobato et al. (2005) should be presented. A new guided discussion based on this article is then proposed. Finally, the teacher should lead a discussion guided by questions to be thought about, such as, And the Immune System...How does it fit this context? How does it work? Students are provided with texts on the history of Immunology, which should be read to be discussed the next meeting, together with articles by Lobato et al. (2005) and Porto and Ponte (2003) as supplementary reading.

The beginning of the movie "Yu-Gi-Oh!TM" (35 minutes), as an advance organizer for the central idea of homeostasis. The teacher should check whether the game Yu-Gi-Oh! (and/or others of the same type) presented in the movie are already familiar to the students' group. After this movie presentation, the teacher should introduce a problem-situation (Is it possible to establish a link between the rule of the game with the work/function of the Immune System and the maintenance of life in the "living world"?) at an introductory level aiming at favoring the relationship between the students' prior knowledge about the game Yu-Gi-Oh!TM with homeostasis, a central idea in the study of Biology. Thus, the major objective here is o prepare students for the presentation of what it is aimed to teach, Basic Immunology .

2. *Initial problem-situations:* a) If the immune system "defends" the organism, how and what happens during this process?; b) What are the structures involved in this process? ; c) And how does the immune system fit this context? How does it work/function? It is recommended that all the questions (problem-situations) and activities be discussed in group with the teacher's mediation.

3. *Revision*[1]: the concepts Life and Living Being should be reviewed. The concept homeostasis has to be focused. The establishment of linkages among the concept homeostasis with other topics already studied by the students in other disciplines they have taken in their course, as well as with

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[1] No início das aulas, de maneira geral, revisar os tópicos trabalhados na(s) aula(s) anterior(s).

the game (advance organizer) should be proposed. The use of the educational/didactic game Immunostase card game2 that has a similar mechanics3 to the one in the movie they watched should be suggested, together with the construction/development of new cards for this game.

4. *Teaching process (6 meetings):* based on a schematic image, there is the identification of the systems that constitute the human organism that is followed by the presentation of a new problem-situation: What results from the interaction and functioning of all these systems in the human organism? With the obtained answers, which are written on the board, presentation of instructional/educational materials can start. The following topics are introduced: the concept of immunity, primary barriers of the organism, Immune System anatomy, and inflammatory response. As a task, a list of exercises (with open questions) to be solved for the next meeting is handed in to the students. They are asked to think about the possibility of constructing cards , which should be grounded on the previous contents, as well as on their academic and personal experiences.

Next, students perform the activity of "correcting" the list of exercises, aiming at promoting negotiation and sharing of meanings. That is, there are small group discussions that are followed by a large group debate/discussion in order to present a proposal for the collective solution to each of the questions.

Afterwards, questions that are already familiar to the students are presented, such as, What is(are) the role(s) of the Immune System in the organism? and What is the result of Immune System action on the organism? Non-familiar question are also added, such as , Comment on these sentences: Infecting agents are common, but infections seldom occur; There are more bacteria in the organism than human cells; Describe the action of the Immune System on Sleeping Beauty' s organism after she pricked her finger in the spindle; What are the main physical features of an inflammatory process? It is suggested that the answers to these questions be corrected in the same format that was used in the exercise list. This "correcting" procedure targets at "inculture" students to the practice of sharing and negotiating meanings to solve different types of questions (situation). Such a practice generates situations in the teaching context that are fundamental to the meaningful learning process and, besides, can favor students'' verbalization about the topic being handled in class.

Topics on antigen processing and presentation, as well as clonal selection should be set forth to the students. Animations4 should be used to illustrate the dynamics of this process. At the end of the meeting, questions that facilitate integrative reconciliation of ideas that have already been presented and discussed are proposed/suggested: What is the result of the Immune System action on the organism? What is its relation to the other systems that constitute the organism?

Following that, the sequential organization/ordering of listed immunological events is proposed/suggested together with the solving of three questions: Does the sequence of events you numbered in the previous question refer to which type of immune response, cellular or humoral? Justify your answer. b)Did the lesion suffered by the organism that performed the aforementioned immune response effect the blood vessels? Justify your answer. c) Describe some other strategy the organism could have used to get the same type of response mentioned in question 01.

Next, the following topics should be presented: immunological memory, immunoglobulin, immunological tolerance, hyper sensibility, self-immunity, and immunological deficiency disease.

[2] Jogo desenvolvido por Andrade (2011), no contexto do Mestrado Profissional em Ensino em Biociências e Saúde, Instituto Oswaldo Cruz, Fiocruz/RJ.

[3] http://www6.ufrgs.br/favet/imunovet/animacoes/mhci.html /http://www6.ufrgs.br/favet/imunovet/animacoes/mhcii.html

5. *New problem-situation at a higher complexity*: retake/go back to the game Imunostase Card Gam and suggest students to establish linkages among the immunological events , the possible cards, and the play strategies concerning the didactic game to be used with the effects of each play in the organism of the opponent/adversary player. This stage will take two or three meetings.

The case study "The boy that does not produce antibodies"(O menino que não produz anticorpos) published in Folha de São Paulo , 28/06/2009, should be proposed here. This activity will consist of solving the following questions: Write a text presenting some possible explanations for what happens in Vitor's organism. Why does it happen? Do people with primary immunodeficiency have difficulty to overcome/beat/ defeat infections? What would you suggest to solve for good Vitor's immunological problem?

Vaccination/immunization tables proposed by the Ministry of Health and the Brazilian Society of Pediatrics should be presented to the students. Based on these tables, students should solve questions such as: a) What reasons can justify immunizations early in people's life? b) In your opinion, why are there differences in the immunization/vaccination timetables/calendars/agendas suggested/proposed by the Ministry of Health and the Brazilian Society of Pediatrics?

6. *Evaluation:* learning evaluation will be grounded/based on the students' work, teacher's observations, and on a formal evaluation.

7. *Final integrative meeting*: in this meeting, the whole contents of the PMTUs are to be retaken, cases and activities will be reviewed, and play strategies already handled in previous meetings. The relation of the central idea with all the topics studied in class should be emphasized. It should also be stressed here the difficulties in studying and researching the theme/topic, the relevance of this knowledge for a better understanding of health and disease, advances in research and in knowledge production that can lead to changes and/or rejection of better explanations for immunological events.

8. *Evaluation of the PMTUs:* This will be derive from meaningful learning evidences , which were, or were not, obtained throughout the development of all the activities.

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ANNEX 4

PROPOSING PMTU TO TEACH CHEMICAL EQUILIBRIUM

Agostinho Serrano*

Objective: to teach the concept of Chemical Equilibrium at High School level within different representation forms/levels/degrees/stages of a chemical phenomenon.

Sequence:

1. *Initial situation:* performance of /carrying out an experimental demonstration or a video presentation about the influence of temperature on Chemical Equilibrium $N_2O_4 \Leftrightarrow 2NO_2$. It should be explained that NO2 is a brown gas, while N2O4 is a colorless gas.

2. *Problem-situation:* it should be explain, using the chalkboard, the direct reaction $N_2O_4 \Rightarrow 2NO_2$, which results in the formation of a brown gas, and the reverse reaction $N_2O_4 \Leftarrow 2NO_2$ that results in the formation of a colorless gas. The students, then, are asked how it is possible for the gas presented in the sequence (1) to change its color according to the temperature. Does the chemical reaction "stop", when color stabilizes? If the chemical reaction "stops", will it restart when we change the temperature? How can a chemical reaction "stop", if molecules are in constant movement? If the reaction does not "stop", how does color stabilize? These problem-situations should be discussed in the large group with the teacher's mediation.

3. *Dialogued lecture:* the teacher, at this point, introduces the concept of dynamic chemical equilibrium, counterpointing it to static chemical equilibrium, always relating it to the fact that a chemical reaction does not "stop". Prior concepts of direct and reverse/reversible reaction should be used, as well as the concepts of reaction speed and concentration. Thus, the symbolic representational level/degree/rate (chemical formulae/s) , shown on the blackboard, should be used. Finally, students get to the concept of equilibrium as that of the coexistence of both reactions (direct and reverse/reversible), at the same speed/rate. So, progressive differentiation occurs based on an initial problem-situation(2) that will be used as an advance organizer and, eventually, through the integrative reconciliation of the concepts of speed, concentration, and direct and reverse/reversible reaction, students get to the concept of chemical equilibrium.

4. *New problem-situation:* it is suggested here that the teacher use the free computer simulation Equil v. 2.01, in which chemical equilibrium is explained by using simultaneously the three representation2 levels of a chemical phenomenon (Gabel, 1993). The problem- situation complexity level is the same, but different representations (different invariant operators) are introduced and they should be individually handled and understood (progressive differentiation stage) and, then, integrated so that all stages of the chemical reaction occur, from the beginning, with reagents that produce/form products in direct reaction, going through/proceeding through the reverse/reversible reaction speed increase until equalization of these speeds reach chemical equilibrium can be

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[1] Available at: http://www.gabriela.trindade.nom.br/equil-v1-portugues/

[2] that is: symbolic (equations, graphs); sensorial (combination color and smell); microscopic (molecules)

understood through the simultaneous comprehension of all levels of representation. Next, the construction of a concept map , in small groups, is suggested allowing for their presentation to the large group, which should be followed by a classroom discussion of the maps aiming at answering the previously proposed questions.

5. *Individual summative evaluation:* based on individual evaluations, as chemical equilibrium problem-situations , the teacher should ask students on their understanding of the equilibrium phenomenon (Orlandi, Camargo e Serrano, 2006), always observing (but not onlly) whether there are evidences of :

- Understanding graphs for concentration of the direct and reverse reactions (symbolic level);
- Understanding graphs for speed of the direct and reverse reactions , getting to equal values when in equilibrium (symbolic level);
- Understanding the meaning of the double arrow in the chemical equation as the simultaneous occurrence of direct and reverse/reversible reactions, and the use of larger arrows to represent a direct reaction with higher speed at the start and vice versa (symbolic level);
- Skill of constructing mental models capable of representing molecules in way that is adequate/acceptable to high school level and its objectives (bidimensional and tridimensional molecules, even spheres representing molecules if the student understands that this is just a representation that has been simplified to its highest degree—microscopic level);
- Skill of making the molecular representations mentally move, sometimes not crashing and sometimes crashing, and, when crashing , such representation are able to react chemically in a direct way (reagents -> products) or in a reverse//reversible manner (products -> reagents), (microscopic level = molecular models);
- To be able to , within this mental model, understand that the formation rate of products is equal to the one of the reagents, and that this reaction does not “stop”, which explains the color stability of the combination (macroscopic level = sensorial).

6. *Final lecture class:* the teacher should use the already studied concepts, explained in all representational levels, to discuss classic examples in which the concept of chemical equilibrium has been stressed to emphasize the relevance of understanding each of the points comprised in the individual summative evaluation (stage 5) for the cultural-scientific formation of the student. The role of Napoleon Bonaparte’ s campaign in Egypt should be explained using the figure of the chemist Claude Loius Berthollet (Bensaude-Vicent & Stengers, 1992) to establish the concept of chemical equilibrium . Other examples to be mentioned are the one of ammonia synthesis and its war application in the Haber-Bosch process (Brown, Lemay and Bursten, 1999), or daily life instances in nature, such as the formation of stalactites and stalagmites, triggered by reversibility of reactions (Kotz & Treichel, 2002), as well as other phenomena such as photochromatic lenses and the reversible reactions of carbonic acid in soda pops/refreshments/drinks.

7. *Learning Evaluation in PMTU:* the teacher should record evidences of meaningful learning through the acquisition and mastery of different representational levels that the students have not used before within this conceptual field. In addition, these representations should be articulate and used in the solution of problem-situations typically concerning chemical equilibrium (problems of the algorithm type), and also to explain the concept of chemical equilibrium as well as chemical equilibrium situations to their peers and teacher. If the teacher verifies that the acquisition of these representations has made the concept of chemical equilibrium more natural to the students, then it is possible to infer that meaningful learning has occurred.

8. Evaluation of the PMTU itself: the PMTU can be considered successful when there has been a progressive mastery of the concept of chemical equilibrium through the acquisition of different representational levels, adequately articulate and able to generate meanings for the concept of chemical equilibrium.

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