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**Abstract**
Different significance of collaborative concept mapping and collaborative argumentation in Case Based Learning are discussed and compared in the different perspectives of answering focus questions, of fostering reflective thinking skills and in managing uncertainty in problem solving in a scaffolded environment. Marked differences are pointed out between the way concepts are used in constructing concept maps and the way meanings are adopted in case-based learning through guided argumentation activities. Shared concept maps should be given different scopes, as for example *a)* as an advance organizer in preparing a background system of concepts that will undergo transformation while accompanying the inquiry activities on case studies or problems; *b)* together with narratives, to enhance awareness of the situated epistemologies that are being entailed in choosing certain concepts during more complex case studies, and *c)* after-learning construction of a holistic vision of the whole domain by means of the most inclusive concepts, while scaffolded-collaborative writing of narratives and arguments in describing-treating cases could better serve as a source of situated-inspired tools to create-refine meanings for particular concepts.

**Resumen**
El mapeo conceptual y la argumentación colaborativa son utilizados en la estrategia de estudios de caso con la ayuda de andamiajes conceptuales. Se discute y comparan las respuestas que los estudiantes dan a las preguntas de enfoque, prestando atención a las habilidades de pensamiento reflexivo y el manejo de lo incierto en la resolución de problemas. Se observan marcadas diferencias entre la manera en que los conceptos son utilizados en la construcción de mapas conceptuales, y la manera en que los significados son apropiados durante la resolución de problemas mediante actividades guiadas de argumentación. Los mapas conceptuales compartidos pueden tener diferentes perspectivas, por ejemplo: a) como organizadores previos, que sirven de soporte, mediante el uso de un sistema de conceptos, para acompañar las actividades de indagación en la solución de problemas: b) junto a narrativas, permiten ampliar la toma de conciencia de la relación entre los conceptos utilizados, y las posiciones epistemológicas asumidas en la resolución de problemas y casos complejos, y c) para después de la experiencia de aprendizaje, como una visión holística del dominio (de conocimiento) completo, integran los conceptos más inclusivos, mientras se ayuda a la escritura en colaboración de narrativas y argumentos que describen y discuten los casos estudiados, este enfoque puede servir como una fuente de herramientas situadas de inspiración para desarrollar y refinar los significados de conceptos específicos.

**Keywords**
*Generalized Concept Mapping, bottom-up concept mapping, case-based learning (CBL)*, pre-*concept, Scientific concept*

**Palabras clave**

## 1. Introduction

The purpose of this paper is to lay down the foundation for a combination of strategies to enhance reflective thinking, to drive high school learners toward intellectual modes [Donaldson 1992] and to enhance their processes and social skills, in a three-year longitudinal experiment that is aimed to cognitively and affectively empower the students[1].

The main strategy is based on the proposal of inquiry activities (problems, case study) through collaborative writing of online argumentation with the new feature of Google Apps Comments (asynchronous) and instant messaging (synchronous discussion), both supported on Google Drive documents and mediated by teachers' feedback. The idea is that through this prolonged activity, a reflective aptitude towards knowledge construction will be slowly regenerated, after years of "intake" of knowledge through repetition and mechanical application of rules.

## 2. Concept mapping vs inquiry based learning

Provided that meanings and concepts arise in problem solving for the sake of arguing or representing cases in situated contexts through narrative or argumentation, the aforesaid activity is excellent to tease out new meanings and to familiarize students with newly introduced concepts (respectively: bottom-up and top-down processes), but it is not the best way to organize a conceptual domain in a hierarchical system, for which concept mapping can be proficiently adopted.
In every case we want to avoid learning by rote, as seen in the intake of "pre-packaged" information, definitions and notions that won't be challenged in any way.

There are indeed important differences in the de-construction and re-construction involved in concept mapping (even if there is a focus question to answer) and in inquiry-based learning. In the former it is more likely that the student will resort to accepted rules and definitions, no matter if s/he does or does not know the anchorage of those rules to concrete mechanisms or instances. This leads to static meanings controlled by symbolic, iconic or logical functions in a formal system rather than to awareness of their effectiveness to represent concrete situations, to serve a precise role in solving a given problem or a controversy.

Yet, as we will see in more detail in the "eight concepts" paragraph, students are used to constructing concept maps that follow associative paths starting from particular views and going towards multiple differentiations, while leaving the "high-rank structure" of the most inclusive level of the cmaps poorly organized and with frequent indications of misconceptions or omissions of the most inclusive concepts.

On the other side, from the first monitored cases we also see that, in discussions stimulated by close-guided inquiry-based learning through focused questions, arguments undergo radical movements, shifting from one domain to another that carries completely new embedded meanings. So, provided that we want to minimize learning based on acceptation and promote the most inquisitive learning, concept maps will be made by the students after they will have tackled real cases, examples and problems, where arguments are put forward spontaneously and actions are accomplished for a precise purpose, even if students don't master formal-systematic definitions for the implied concepts. We want to recover the positive pedagogical function of errors (which are so frequent in inquiry-based learning) and of social negotiation, debates and argumentation in making inter-subjective meanings that can be gradually and consciously fitted to match with formal-academic meanings.

Reflecting during concept mapping is typically directed to find a better and simpler organization of concepts or to find more suitable and precise linking words or qualifiers for relations and concepts that are already placed in a learner's working memory. Rarely, a student bases himself or herself on the associative network of concepts to create some higher rank of generalization. S/he needs scaffolding from the teacher even to "feel" the necessity of some inclusive concepts and/or general setting to organize the whole layout (see an example in Fig. 1).

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[1] Collaboration includes 27 students of classes 3CH of the author of this paper, and 3L of Silvia Recchia from Istituto Galileo Ferraris of Verona.

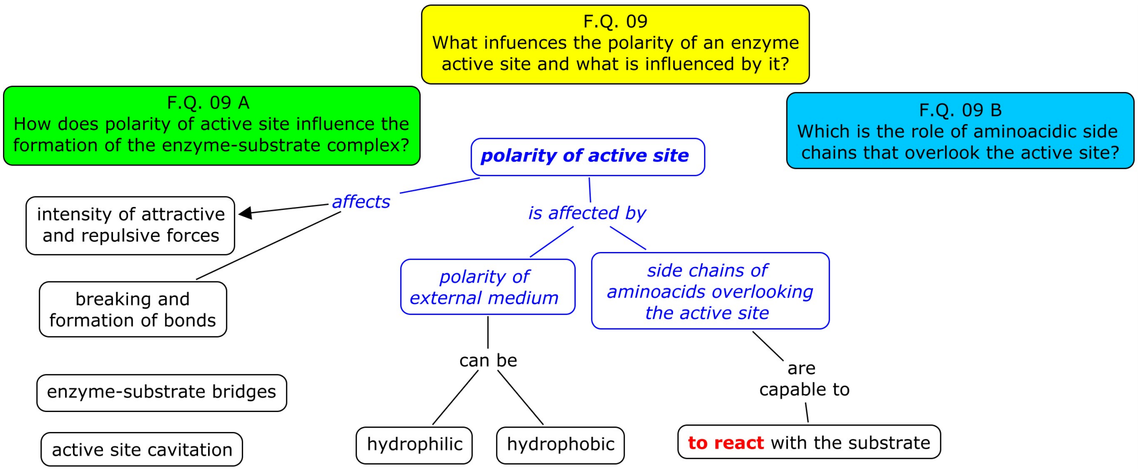



Figure 1. The original-complex focus question about enzymes (not shown) was divided into a simpler and more general question (central-top box) and into two sub-questions, F.Q. 09 A and F.Q. 09 B (colored left and right top boxes), after the students of the team started to connect concepts directly from the second level (black). The need of more inclusive framework (blue-italics first level) was obtained by persuading them in a few minutes. The left side of the progressing cmap shows two other concepts that remained parked for future development.

In inquiry-based learning reflection typically consists of re-reading and re-writing the terms of the problem, re-reading others' statements, suspending or redirecting concentration to read another source, being receptive to any clue that could help to discover or to challenge illicit assumptions (if the process is stagnant) or to find out some starting idea (if the process haven't started yet). In reflecting for inquiry, learner's working memory is often occupied by an overload of irrelevant information and preconceptions, which block the process; while in concept mapping the process flows more regularly, especially if it is helped by concepts pre-collected in a "parking-lot".

On the other hand, scientific inquiry, as problem solving, has just to do with a "what to do when all the paths of thought seem to be barred" kind of situation and there is just one way to learn the necessary ability to overcome that condition: to *get into* that situation (that is intentionally avoided by traditional instruction) *repeatedly*, to come back to the subject after some time, and then attempt to solve it, thanks to both one's own resources and collaboration from other people in the learning community. This is in conflict with the tendency of most students to prefer "only one access to knowledge", that determines the well-known negative chain: dependence on the teacher → vanishing of critical skills → inclination to a-priori giving up any challenge.

## 3. Eight concepts

As described in the previous paragraph, analysis, start and development of case-based inquiry learning is a matter of continuous realization of the usefulness of concepts and meanings as applied in situated contexts. There are no repeated applications of algorithmic procedures, and all cases are qualitatively different, but there are several recurrent concepts that learners become more and more confident with, in bottom-up processes that are activated by this case study.

This is indeed a good approach for familiarizing with single concepts or certain clusters of concepts, but not as effective in constructing a holistic model of a certain knowledge domain. We believe that the degree of confidence with "top rank" concepts is strictly related to the capability to find, understand and face the problem in case study. In other words, familiarity with the most inclusive concepts corresponds to the above stated individual resources that help to both initiate and engage in the inquiry process.

Therefore, we have devised a novel strategy to stimulate the revision of meanings about the most general structures and assumptions of a knowledge domain.

1. A general focus question – with some restrictions and frame requirements – is posed by the teacher and answered in text-form with as much breadth and detail as possible by students, autonomously. The same focus question, without specifications, has

served to introduce the general theme of case studies at the beginning of the module, and to progressively developing a complex concept map of related details to scaffold integration of the newly incoming concepts.

2. From the text-form answer, each student selects or elicits her/his *eight most general concepts*, and "parks" them in a Cmap that is shared with other buddies in a team.
3. The team buddies read the other's answers, criticize them, propose changes and propose-elaborate a "best" single text-form answer that is shared by all.
4. From that best answer, *ten* most general concepts are extracted and parked in a cmap.
5. A cmap is collaboratively made of just a maximum of ten concepts to answer the same focus question.
6. The cmaps of all teams are discussed in the class to enlighten differences in choices and, possibly, disagreements between teams, revealing any residue misconceptions.

While writing this paper we are at the end of the first module about *chemical reactions from the point of view of initial and final substances (reactants and products)* and at the first two steps of this experimental route to help learners mind in "mapping the fundamental (most general) concepts". We aim to help learners to reach a firm general conception of chemical transformation, which is based on the fundamental concepts of *Chemical System, Energy,* conciliating *Structure* and *Substance* levels of representation. It is widely documented that students can apply themselves with a high degree of competence in describing reaction mechanisms and doing stoichiometric calculations while lacking a general and correct representation of what is really going inside the chemical system and of how everything "collapses" in the synthetic balanced equations and energy exchange values [Osborne and Freyberg (1985), Nurrenbern and Pickering (1987-1990), Nakhleh (1993), Nakhleh and Mitchell (1993)]. The overwhelming reduction of chemistry to "managing of symbols" also makes vague and undefined the differences in meaning between entities as stable substance and molecular species that are often unstable. Without these distinct concepts in mind, any direct exposition and observation of chemical phenomena, as could derive from laboratory activities, would never be able to stimulate any learner's conceptual change, which should be the goal of all education.

We started from the beginner's course of Organic Chemistry to set such basis of General Chemistry, so the examples of cases in the case-based learning activities are taken from Organic chemistry, but the outcomes we wanted are absolutely general. Everything is new for both the teachers involved in the task and their third grade (age 16) students, so we are proceeding through cautious steps to optimize the process. Student were so used to preparing "top-down" concept maps about past topics that several of them started to answer the focus question by direct-normal (top-down) concept mapping (e.g. connecting the concepts to the focus question's square) or answering in text-form in a superficial way, while putting concepts in the cmap that were significantly different from the answered text. As a lesson for the future, for the next subtopic (that is already running) we will use Google docs and collaborative writing for the second and third steps and only then we will pass to concept mapping in the proper - dedicated environment (Umaps – CmapTools), separating the bottom-up reflection on the fundamental concepts from the reproduction of the elaborated and negotiated system of concepts in a concept map.

The first answers from the learners, reported in the following examples, demonstrated that an apparently simple task, such as explaining what happens in a chemical reaction, received inadequate answers from a conceptual point of view, notwithstanding the fact that a lot of sophisticated concepts and differentiations were used competently by the learners during the main activity of case study. So, as an example, many students ascribed a high rank to the *classification* of chemical transformations in Exothermic and Endothermic; they were classifying everything: Chemical Bonds, Reactants etc., but forgetting to talk of the Chemical System, the "stage" in which everything happens. That once more showed us the tendency of students to articulate concept maps as outlines of increasing completeness of details, but with scarce integration in a wide-range generalization, that would entail a higher level of awareness of inclusive concepts' meanings. The following table summarizes the concepts that were elicited by the answer to the focus question "*What does occur to a chemical system that undergoes a chemical reaction, considering the energetic and structural point of view of reactants and products only?",* sorted for number of occurrences.

| ***Students:*** | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 | S11 | S12 | S13 | **total occurrences** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***CONCEPTS*** | 12 | 9 | 12 | 8 | 7 | 8 | 9 | 8 | 7 | 9 | 5 | 8 | 6 | |
| reactants/products | 5 | | 5 | | 1 | 2 | | 1 | 1 | 3 | 1 | | 5 | 24 |
| reaction (chemical) | 6 | 2 | 4 | 1 | | 4 | 2 | | | 4 | 1 | | | 24 |
| chemical system | | 3 | 8 | | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | 3 | 21 |
| endothermic/exothermic | 5 | | 3 | | | 2 | 2 | | | 2 | | | 2 | 16 |
| chemical bond energy | 1 | 1 | 4 | | | 1 | 1 | 1 | 1 | 2 | | 1 | | 13 |
| molecular skeleton | | 3 | 2 | | | | | | 1 | 1 | | 5 | 1 | 13 |
| chemical bond: covalent | 3 | | | | 1 | 2 | 4 | 1 | | | | | | 11 |
| energy/enthalpy of formation | 2 | 1 | 2 | 1 | 1 | | | | 1 | 2 | | | | 10 |
| heat (absorbed/released) | 4 | | 4 | | | | | | | | | | | 8 |
| chemical bond: single/multiple | | | | | | | 3 | 1 | | | | 3 | | 7 |
| connectivity change | | 1 | | | | | | | 1 | 2 | | 1 | 2 | 7 |
| Molecules | | | 1 | | | 2 | 2 | 1 | | | | | 1 | 7 |
| chemical bond | | | | | | | | 1 | 1 | 3 | 1 | | | 6 |
| substance(s) | | | | | | 2 | 2 | 1 | | | 1 | | | 6 |
| chemical bond cleavage | 1 | 1 | 2 | | | | | | | | | | | 4 |
| chemical bond formation | | 3 | | | | | | | | | | | | 3 |
| chemical bond: ionic | 3 | | | | | | | | | | | | | 3 |
| configuration change | | 1 | | | | | | | | | | 2 | | 3 |
| atoms tied together by their bonds | | | | | | | | | | | | 2 | | 2 |
| electron shared | 2 | | | | | | | | | | | | | 2 |
| Reaction: Carbon hydrogenation | | | | | | | | | | | | 2 | | 2 |
| Reaction: hydrogenation | | | | | 1 | | 1 | | | | | | | 2 |
| aggregates: covalent-continuous solids | | | | 1 | | | | | | | | | | 1 |
| aggregates: ionic solids | | | | 1 | | | | | | | | | | 1 |
| atomic electron exchange | 1 | | | | | | | | | | | | | 1 |
| atomic energy levels | | | | | 1 | | | | | | | | | 1 |
| atomic orbitals | | | | | 1 | | | | | | | | | 1 |
| chemical bond dissociation energy | | | 1 | | | | | | | | | | | 1 |
| element(s) (given) | | | | 1 | | | | | | | | | | 1 |
| energy/enthalpy level | | | | 1 | | | | | | | | | | 1 |
| heat of combustion | | | | | | | | 1 | | | | | | 1 |
| intermediate state | | | 1 | | | | | | | | | | | 1 |
| mass conservation (law) | 1 | | | | | | | | | | | | | 1 |
| structure | | | | 1 | | | | | | | | | | 1 |
| transformation | | | | 1 | | | | | | | | | | 1 |

*Table 1. Collected "eight concepts" from the first individual concept lists*

Students that exceeded 8 concepts were constructing the concept map before or simultaneously to the text-form answer to the focus question. Their occurrence numbers for each concept indicate the number of propositions showing the concept at a node (isolated concepts should get a zero rank, but they were rated with "1" for coherence with simple concept lists). Cases with less than 8 concepts, were due to the students' choice to differentiating between multiple concepts that were counted as single concept in the table (e.g. exothermic/endothermic; reactants/products; etc.) The total occurrence numbers permit to have a first impact of the most rated concepts, that could be compared, for example, to an hypothetical answer and rated list from a teacher: "A *chemical system* which undergoes a *chemical reaction* changes its state due to a *rearrangement of its atoms* that leads to different final-*stable species* from the starting molecular species. These species correspond to observable *reactant and product substances* that are characterized by different structures and have different stabilities which depend on their *intra-intermolecular bonds* and are measured by their *enthalpy of formation*. These *structural changes* cause the final and initial states of the system having *different energy or enthalpy levels,* difference that is exchanged by the system with its environment and appears as *absorbed or released heat*." These concepts can be partially retained/modified in constructing a cmap (Fig. 2)

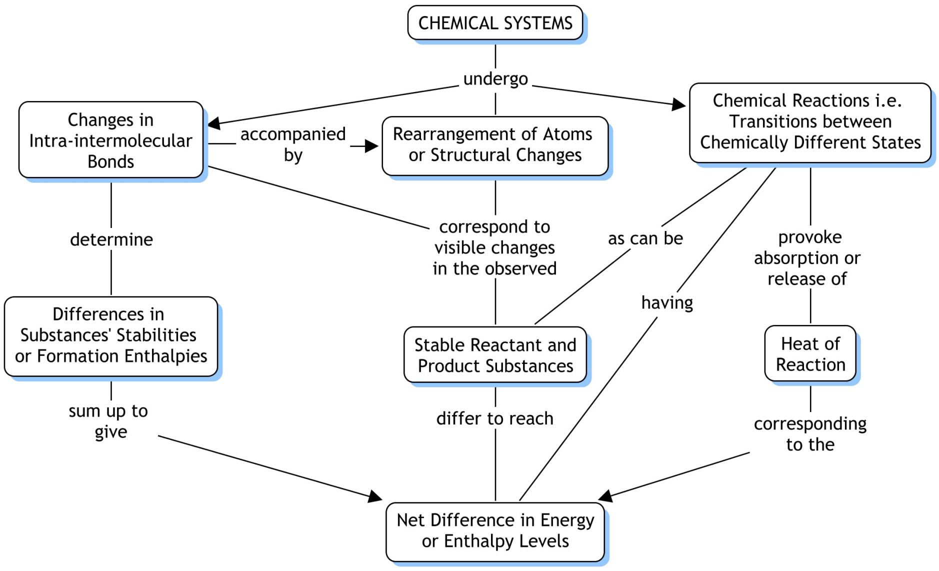
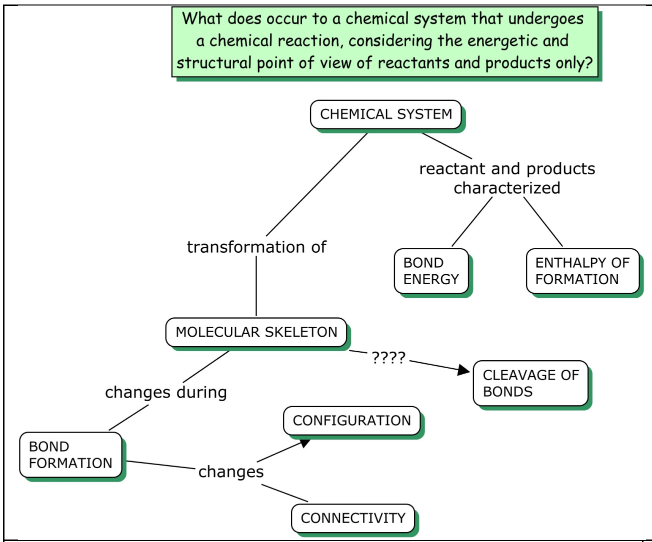


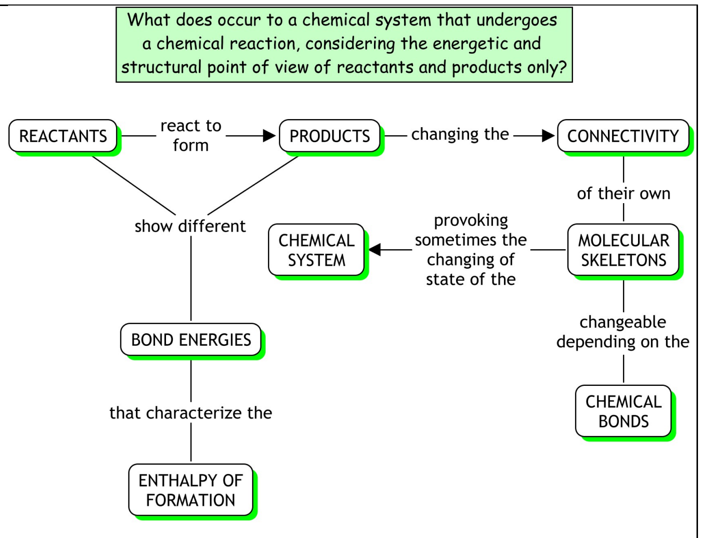

*Figure. 2 A possible teacher's cmap based on the text-form answer to the focus question.*

The occurrence-number table of this cmap is as follows:

| | |
|---|---|
| - changes in intra-intermolecular bonds | 4 |
| - chemical reactions i.e. transitions between chemically different states | 4 |
| - net difference in energy or enthalpy levels | 4 |
| - rearrangement of atoms or structural changes | 4 |
| - stable reactant and product substances | 4 |
| - chemical systems | 3 |
| - differences in substances' stabilities or formation enthalpies | 2 |
| - heat of reaction | 2 |

"Teacher concepts" are more often expressing relations (e.g. changes, differences in something, transitions between states) or result completed with qualifying attributes (net, inter-intramolecular, stable), and have more interconnections (linking phrases) if compared to students' concepts. The following cmaps are from students S2 and S9.




| | |
|---|---|
| In a reaction there is a passage from reactants to products in which we have a transformation of the molecular skeleton that change in the formation of (single, double, multiple) bonds that are different from the products' bonds, while the system shifts from a state to another. Reactants and products are characterized from different enthalpies of formation and different bonding energies; the formation of new chemical bonds will cause | During a reaction there's a shift from reactants to products that happens when a change in the structure of molecular skeletons occurs that depends on the chemical bonds that are going to form. Consequently the products' bonds will be different from the reactants' bonds. Reactants and products have also different enthalpy of formation and different bonding energies, and with the formation of new bonds the connectivity will change too, while |

| | |
|---|---|
| a change in connectivity and also the configuration of the aggregates. | the chemical system will change its state. |
| TEAM_A: *A chemical reaction means a transformation of structure (of connectivity and configuration of molecular skeletons) consisting in a rearrangement of atoms. This takes place with a formation or breaking of (single or multiple) bonds, causing formation of substances (products) which are different from the reactant substances, that equates to the shift of the chemical system from a state to another. The reactant and product substances are characterized by different enthalpies of formation and by different bond energies. Taking the difference of formation enthalpies of products minus the reactant (all stable substances) we get the overall energy variation of the system.* | |

Figure 3. Two typical "eight concepts" cmaps that were constructed from students S2 (left) and S9 (right) contextually to the text-form answer to the focus question. The individual answers were in the cmap layout in the original cmaps, but here they have been reported below for better readability. The answer below (italics) is the first coming from a collaborative adaptation within S2's team_A.

As in the two examples in Figure 3, the first text-form students' answers were often better descriptors of the correspondent cmaps that were made prematurely (instructions prescribed team collaborative cmaps only, at step six). Student S2 influenced a lot the final text-form answer of his team, subordinating, as an example, the concept of change in molecular 'connectivity' and 'configuration' as particular cases of 'structural change', an important inclusive concept that was adopted from individual answers of the other two team members. Team_A's answer shows many of the inclusive concepts appearing also in the "Teacher" answer (that was made only for the purpose of this article).

These observations support our conviction that text-form type of bottom-up generalization-reflection learning is more effective that than direct concept mapping in rising up the accuracy of learners' conceptions towards the academic ones.

## *4. Conclusions*

We are not sure of the final form of this kind of concept mapping, of how it will be susceptible to adaptation in other future topics, but it will certainly be systematically structured to assure that enough time and energy will be devolved to that part of social construction that is needed to complete the meanings of those few general "words" that are taken for given and discounted in traditional - algorithmic - teaching, avoiding any flight towards lower-level empty words and particularizations. Students will learn that ascribing relevance to this imaginative undertaking, connecting the studied cases to general claims, is as important as solving the cases. We believe, in such way, to obtain a well integrated system to get a complete heuristics to facilitate up and down movement along the meridians of a conceptual system as described by Lev Vygotsky [1986]. This would facilitate those developmental changes in the structure of generalization that could be expected by sixteen-years-old students facing with the first very intellectual tasks. To define what we mean with these tasks we may quote in the second appendix some Vygotsky's [1986] and Donaldson's [1992] references, containing some relevant and partially superimposable passages that are guiding our research.

## 5. Appendix 2

> "The rise from preconcepts [...] to true concepts, such as the algebraic concepts of adolescents, is achieved by *generalizing the generalizations* [italics added] of the earlier level [...] The new, higher concepts, in turn, transform the meaning of the lower. The adolescent who has mastered algebraic concepts has gained a vantage point from which he sees concepts of arithmetic in a broader perspective. We saw this especially clearly in experimenting with shifts from the decimal to other numerical systems. As long as the child operates with the decimal system without having become conscious of it as such, he has not mastered the system, but is, on the contrary, bound to it. When he becomes able to view it as a particular instance of the wider concept of a scale of notation, he *can operate deliberately* [italics added] with this or any other numerical system. The *ability to shift at will from one system to another* [italics added] [...] is the criterion of this new level of consciousness, since it indicates the existence of a general concept of a system of numeration." Vygotsky [1986, p. 202-3]

Donaldson [1992] distinguishes two modes of intellectual functioning of the mind: 'construct' and 'transcendent', corresponding to different stages of development (the second not being always reached by all the individuals). In general terms:

> "Beyond the line mode the major step that is taken consists in *movements towards the impersonal* [italics added]. That is, the mind starts to be able to function in ways that achieve some *independence from personal goals* [italics added]. For instance*, it becomes possible to think about problems of some generality* [italics added] […] On the other hand, it is also possible for human beings *to think with the aim of understanding some aspect of the way things are* [italics added]. In this sense there is movement towards impersonality, though the movement may be powered by intense personal curiosity. […] The process of 'opening out' in those two directions is the one that I have previously called *disembedding.*" [Donaldson, (1992) from the introduction, p.16-17]

Later on, Donaldson defines the 'construct' variety of concern in intellectual modes:

> "What has to be achieved beyond this is the movement of the locus of concern away from particular happenings in time. Instead of here/now or there/then the mind will next begin to concern itself with a locus conceived as somewhere/sometime or anywhere/anytime. […] We start to be actively and consciously concerned about the general nature of things. […] The needed context is, by definition, no longer provided by the perception of specific events, by the memory of them or by the anticipation of them. So it has to be supplied by a *deliberate constructive act of imagination* [italics added]. For this reason […] it is called the construct mode." [ibid. p.80-81]

A similar example to Vygotsky's idea of movement towards generalization can be quoted, also to clarify Donaldson's meaning of 'embedded/disembedded': "What is involved in the mind's movement from 'seven fishes' to 'seven' is abstraction indeed, but it is more: it is a dramatic decontextualization. In the contexts of our ordinary life we have to deal with quantities of fishes, but we never encounter seven. […] A pure number resists embedding in any human context." [ibid. p. 90] .

The grasp of general concepts is a momentous development for the gained independence of thought, but the imaginative activity we call "making sense" becomes even more useful in the transcendent modes, described as the most advanced modes by Donaldson:

> "We move on now from the intellectual construct mode to a further mode that is also intellectual, yet radically different. I shall call it transcendent mode. […] I stress again that this does not mean they are unemotional. It means only certain kinds of emotion - the kinds liable to distort or bias thinking – are excluded by definition. For where potentially distracting emotions are present to any appreciable degree the mind has shifted gear and has slid back into one of the core modes – a shift that remains always easy and tempting. […] In the case of intellectual transcendent mode, [however,] the concern is no longer about something that could happen 'sometime, somewhere'; and the need for imagined setting has dropped away.[…] To speak paradoxically, we may say that the focus of concern is nowhere. […] The prototypical activities of the intellectual transcendent mode are logic and mathematics. But […] what […] are logics and mathematics *about*? […] The general answer has to be that logics and mathematics are about *relationships*: relationships of compatibility or incompatibility, of symmetry or asymmetry, of inclusion or exclusion, of equality or inequality, and so on. More than this: they entail the systematic study of *patterns* of relationships. […] A shift of concern from things-in-relation to *relations themselves* [italics added] is made easier if the dominance of 'things' can be diminished. But that dominance is powerful indeed, and hard for our minds to reduce. It is harder still to give up entirely the construct-mode habit of thinking about imaginable entities of some kind, even if their individuality is diminished to the limit. This means that the diminishing of individuality is not a sufficient condition for the shift to *concern about relations* [italics added], though I think it is a necessary one." [ibid. p. 125-126]

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