Concept Mapping to Learn and Innovate
Proc. of Sixth Int. Conference on Concept Mapping
Santos, Brazil, 2014

CONCEPT MAPPING AND THE DEVELOPMENT OF ARGUMENTATION IN THE ZPD

Alfredo Tifi, ITTS Divini San Severino Marche
Email: alfredo.tifi@gmail.com

Abstract. A new strategy of organizing argumentative text and connecting this activity to concept mapping has been successfully realized through a series of recent experiments during curricular in-service activities with two groups of adolescent students of chemistry in the context of Case Based Learning. The preliminary results, along with the reasons and the conditions for taking advantage of the argumentation activity as a form of making and transforming newborn meanings, as well as of mediating an increase in the development of thinking in scientific concepts, will be discussed in comparison with concept mapping. The possible relevant role for concept mapping in the whole strategy will be also re-considered.
Keywords: Concept Maps, Case Based Learning, Argumentation

1 Introduction

The age called adolescence takes the child through a profound and qualitative evolution to thinking in concepts. This in turn makes the child understand him/herself as a thinking person, leading to a crisis in identity/personality, which also helps in building a world view, as occurs with gradual changes during adolescent's development (Vygotsky, 1998). There are many studies, including neurological (for example, see www.bbc.com/news/magazine-24173194), demonstrating that the way in which information is processed undergoes dramatic changes during the age of adolescence. These changes are certainly related to the way working memory is used (Baddeley, 2002).

Margaret Donaldson (1987, 1992) describes this stage of the intellectual development as the onset of the capability of the child to consider, or "observe" his own thinking on perceived objects or events, to listen to or read words, separate from objects or events denoted by those words. Vygotsky (1998) made a fundamental contribution in clarifying the essential role verbal (inner) thinking and social and cultural interaction play in the construction of meaning and in the development of adolescents' personalities. By combining Vygotsky's and Donaldson's ideas we can deduce that the changes in the speaking/thinking system of meanings (Mahn, 2012) are mainly affected by the use of language, over other minor factors. Words, as signs, are needed, consciously or not, to internally *control* the flow of images and to express innermost forms of meaning or representation, in speaking to and in interpreting other people's speech. Also, the mastery in the use of linking concepts (such as "because" and "although", which were the object of empirical studies by Vygotsky, 1986) in everyday language and in the instructional environment, is highly related to the development of a new structure of thinking that is required to argue or reason.

Therefore *Argumentation* (not only scientific) becomes possible (but not necessarily actualized) as a result of these changes, because the related analysis, detachment, suspension of judgment, and order, are all consequences of the discovery that thoughts can be "captured" in different alternative forms, utterances, or *knowledge claims*, that may suitably carry different meanings, questioning, comparison and connection.

Before the development of thinking in concepts, spoken utterances and written claims reflect directly thoughts, where the most frequent connectors between the speech units are "and", "then" or equivalent.

The zone of development for "thinking in concepts" represents, for the adolescents, the differential of the possible movements among different structures of generalization attainable with or without adult assistance. These structures of generalization range from the ones that are directly related to the objects and events (i.e. pseudo-concepts), to those which permit a free and deliberate use of abstraction or generalization, and operations such as differentiation and aggregation, as well as inverse operations of exemplification and transformation in terms of everyday concepts.

Everyday language is a way to think in "fossilized" structures, thus binding any development to possible changes in the cultural environment, whereas argumentation, starting from this *foundation*, can be not only a way to communicate, but also to "stretch" thinking & speaking towards the incoming and maturing higher order ways, in which the educational environment can make a difference. The modifying environment for the

achievement of advanced argumentation can be created as sets of structured activities, whereby the experience and the processes in using-sharing new “possible utterances” slowly shifts between the two levels:

Initial: verbatim-fragmented discourses with purely associative connections, lists of unrelated sentences or words, that attempt a direct answer to the problem posed; there is a tendency to take into account only a few terms of the focus-question at issue, because students have difficulty in considering the issue as a whole.

Final: highly connected processes of argumentation and synthesizing, that include an introduction or contextualization, a central and essential thesis, and a conclusion, where the different ideas are coherent to the sake of describing a whole structure, justifying a thesis or explaining positions linked by supporting evidence and causal or logical reasoning.

The adolescent-learners' zones of proximal development are processes in maturation somewhere in this interval. Given that argumentation is a sophisticated function of language, it is helped by reducing inquiry and epistemological challenge, while maximizing student-student interactions and dialogical function of language.

The language of *Concept Mapping* can be viewed as a further level of synthesis in respect to oral and written argumentation, as a concept map can be considered a dynamic source of possible spoken arguments. The concept maps that have been made after such a development has become possible, can be called “assertive”. Managing the further level of synthesis that is required in concept mapping is more difficult than in arguing because of a needed mastery in understanding and *transforming* the relationships between knowledge and concepts. The latter can be constructed to a deeper level thanks to oral and written collaborative argumentation as mediational tasks. Consequently, as long as the learner is unable to imitate a process of arguing, it is only possible to make a pseudo-concept map in which concept labels are connected by “assonance” relations, or they are simple classifications (whole-part relations), lists of feature words (as in mind maps), or reproductions of narratives in the X-Y plane (diachronic relations). Concept maps from students who have not developed argumentative thinking are invariably of this “descriptive” type. Even for skilled cmapper-teachers is quite difficult to respond to a "why-type” focus question, thus a partially descriptive structure is virtually unavoidable.

As we will see next, it is not necessary to add cyclic structures or to search for more complex structures in concept mapping, in order to give a concept map an explicative, mechanistic, or “demonstrative” function, because linearly written arguments can fulfill and scaffold these functions more easily.

2 Preferring argumentation as mediational strategy

The slow and written construction of coherent links between claims, warrants, and data, requires a voluntary "segregation" of what is being required in the task, to differentiate the generally different nature between factual data and claims. Therefore, the repeated application of this task and the progressive removal of teacher’s support can help to extend the zone of proximal development of thinking in concepts over time.

Two different types of claims were elaborated: simple claims and combined claims. A combined claim puts together and links two declarations by means of a logical connector with the function of explanation (because), justification, support, hypothesis, if-then, consequence, adversity, or simply time-narrative value.

One of the most difficult subtasks in the construction of written arguments is to create the connections between different claims in the perspective of the coherence of the whole text. Only an overt discussion with the help of teacher during the "work in progress" permits the possibility of choosing a better amalgam between several “local” meanings and to better address the whole argument towards the focus question.

The meaningfulness of an argument is displayed at every level: it is in the argument as a whole, in every aspect of a complex argument, in a combined claim, in the specific and contextualized use of every concept in making a claim or proposition. Every level of meaning can be the object of collective-dialogical reflection and can be given a name and a connotation in the process of shared revision, in order to stimulate the development of higher structures of generalization. It is evident that this is a second level of the process to support a written or "objective" argument, which would be impossible to get during a live class debate aimed to argue an issue.

Debate and negotiation-structured activities have been applied, especially in the first part of the project, as a way to orally defend and self evaluate the arguments that were created by the teams in the classroom. These activities resulted as a very useful way to instill a constructivist atmosphere in the whole learning community

and to provide a sociocultural frame for the process. However these activities, accompanied by the "fast-thinking" processes of speaking, are not suitable, or too time consuming, to solicit changes in the voluntary use of the logical connectors and of the meanings associated with scientific concepts; these are indeed two changes which actually demand *slow* & conscious processes, as is viable in written activities. These latter processes are also more demanding in the use of working memory, and this is a further reason to use an objective-written form of argumentation as a mediational base for working in the "higher" zone of development. In fact, in contrast with the discourse-flowing claims the written claims and concepts can be more easily treated or flexibly disembodied as separate objects or 'chunks', and grouped back again in new and different 'blocks'.

A typical function that is demanded of the students is to "detach" themselves from the text and see it from the point of view of a proofreader or another student-reader. This is a very metacognitive function that entails the previously stated flexibility in order to consider different levels of the argument at the same time, and can produce deep revisions in the sequence and structure of text claims.

One reason to prefer argumentative structures to concept maps in the early stages of shared construction of new knowledge is the fact that the structure of written claims is at first similar to the logical structure of oral discourse, that is mostly linear - narrative - thus allowing students to directly capture and retain those utterances, from both the internal and external discourse, that can be mentally re-echoed, shared at different times and transformed, or checked, as internal speech toward an imaginary third person (the listener-proofreader). School tasks of re-reading/reviewing linear texts are more generally trained & accepted tasks than concept mapping.

Another reason for this preference is that written argumentation have the largest degree of freedom in repeating the use of the same concepts and in the choice of logical connectors between claims, including those consequential, adversative or if-then and phrasal structures that are notably tricky to arrange in concept maps.

3 The structured argumentation task in detail

One of the most striking pieces of evidence that the process of argumentation fits the ZPD of adolescents is the observation that the teacher's *efforts* to obtain good written arguments, following certain rules, rapidly decreases from age 16 to 18, tracking the three years of taking courses in chemistry. The encountered difficulties were highest with cause-effect types of argument and lowest with mostly descriptive arguments.

The following - very good - structured argument was "distilled" in an activity (the third of this kind in the year) about 'carbohydrates' in the fourth high school grade. A group of five students (each one coming from a different stable team) first searched for information related to the general topic that was assigned (Topic 1: "The 'Reducing Power' of carbohydrates and the oxidation products"). After the material was assembled by the group members in a Google document from home, the five elaborated the answer to the focus question as a structured argument at school, in a two-hour class. There were two more topics and related focus questions that covered the whole study of the sugar module, and these were assigned to the other two groups. After his/her job on the focus question, every member returned to their original team; there the specific knowledge was shared, and three concept maps were collaboratively constructed that answered the same three focus questions. Then three teams were chosen to present and discuss the final Cmaps to the class. All the 15 cmaps were rated.

FOCUS QUESTION 1: ***Why*** *is also the ketone group of ketoses easily oxidized?*
Argument:
1. To consider a sugar as "reductant", it must be oxidized by weak oxidant agents in basic milieu. This occurs **if the condition is met** in which the sugar molecule is in equilibrium with its open-chain form, **because** the latter is the only one with the free-oxidable carbonyl.
2. In a basic milieu, weak oxidants as Ag^+ and Cu^{2+} ions, contained in the Fehling's, Benedict's or Tollens' reagent, can oxidize to gluconic acids aldoses and ketoses as well, **because** the latter are "epimerized" to the former in basic solution.
3. **By contrast,** only aldoses can by oxidized to gluconic acids (carboxyl in C1) by weak oxidants, as bromine water, Br_2(aq), **if** oxidation is operated in non-basic solution, **because** the aldehyde group only is easily oxidized in absence of epimerization.
4. In epimerization a base subtracts a proton from C1 yielding a symmetric enolate, in which the OH on the C1 can protonate the equivalent $-O^-$ that can be obtained in C2 by resonance. The new enolate-carbanion in C2 is **then** back-protonated to aldehyde by a water molecule.
5. *[new claim to be added by the group]*
6. All sugars are ***then*** *classified as* reductant, **except** those which lack a free anomeric hydroxyl, as glycosidic sugars and polysaccharides. In the latters the unique reductant site, *at one end of the chain*, is not *analytically* detectable.
7. **Indeed**, any sugar *that hasn't been classified as reductant* can be oxidized, by strong oxidants as nitric acid, to aldaric acid, which have carboxyl groups at both chain ends. **Unlike** aldoses, the carbonyl function is kept by ketoses when they are oxidized to aldaric acids.

A few words must be said about this example *structured argument*. Contributions by the teacher were given as advices, to split some complex claim, to change the sequence order for better adhering to the focus question, to eliminate something that was not relevant, to introduce and summarize the complex mechanism in the fourth

claim. All these hints were negotiated within the group and actualized by the group autonomously. During the process of accomplishing the task, it was clear to the learners that an 'imaginary non-expert addressee of the argument' was 'present' in the class. Hence the claims ought to be detailed enough to avoid ambiguity, misunderstanding and shortcoming to this 'person'. Although the material that the students had collected before was really detailed with images and examples (e.g., reaction mechanisms and chemical formulas), to stimulate the use of the most *general* concepts, students were told to use *only words* to construct the argument, and minimize the use of specific examples. Those would had been useful in the concept mapping stage. The few italics words were added by the teacher, who also pointed to a missing link in the chain (why free anomeric hydroxyls make the ring openable) that ought be fixed (claim n.5). For the sake of this article, the ***connecting words*** have been put in bold. These words represent the "welding joints" to yield the meaning of the composed claims and of the whole structure, but are almost untreatable in making concept maps' propositions.

The process steps and criteria to adopt in writing a structured argument are the following.

1. A clearly stated focus question on a very precise and primary issue - not but the overall topic - is assigned.
2. The "answer" cannot be given as a single short sentence or declaration, but as an articulate argumentative text.
3. The argument has to be divided into separate and numbered knowledge claims or ideas, expressed in simple sentences or propositions with subordinate clauses, examples, etc. that, in any case, shouldn't go beyond three lines of text.
4. Every logical connector must be explicit, within the combined claims (e.g.: 'consequence' *because* 'cause') or at the beginning of every new claim.
5. A structure can be given to the argument with a necessary contextualization or premise, a main body, and a conclusion, in such a way to form a complete, connected, and coherent text that can be read as a meaningful whole.
6. concept-labels have to be highlighted in two different colors to select and distinguish a few first-level concepts and a larger number of second-level concepts (those concepts that can be directly connected to the former).

Point six was to prepare the concept-mapping activity. If an argument requires more than a dozen knowledge claims, or more than 20 concepts, it should be split into sub-arguments. In any case, the focus question is always designed to tackle a restricted and yet representative section of the whole topic (a criterion that, incidentally, should be used also in normal concept mapping). This has the function of avoiding purely descriptive answers, or simple lists of facts or events, and of demanding explicit recourse to the scientific concepts and to the functional relationships between them, as well as to a reflection on the new and often unfamiliar related terms.

The strategy is concocted to push the integration of the new, scientific terms in the construction of "natural" sentences, at least from the point of view of syntax rules of normal writing and speaking. On the other side the unnatural set of syntax rules of concept mapping constitutes an obstacle to this sort of stretching from the everyday to scientific discourse, which is aimed in the early stages of tackling new scientific-conceptual domains. Where efforts are not made, or if they are unable to stimulate this kind of integration, the new terms and concepts are only assimilated and re-evoked as "stock phrases" utterances.

4 Forms of training and mediation

In order to facilitate the understanding of the new task of creating an argument as an answer to a focus question to the student teams or to the individuals, several strategies have been used at different times.

a) video examples (http://youtu.be/raG5cm_tdt4), constructing examples or discussing a previous examples in the classroom;
b) from a descriptive textbook page, eliciting the useful parts (for a premise, for the main answer, for the conclusion or a question);
c) selecting the first & second level concepts from a given argumentative or descriptive text and then comparing them in the class;
d) very simple focus questions on familiar content were assigned to answer with at least two levels of causality. In two cases that task was used as an assignment to assess the progress in the collaborative and argumentative skills of the teams. A *rubric* (available on demand) was used for the assessment with five 1-3 ranks for: *a)* respect of form-structure of argument; *b)* completeness-adherence; *c)* cohesion; *d)* internal coherence; *e)* adoption of pertinent concepts.
e) A long chain of causative connections was used to explain in front of the class why one of two acids is stronger than the other, by means of theoretical reasons, starting from *bottom-up* (from primeval causes to the consequences). Everybody was allowed to check the comprehension of every single step. Only the structural or symbolic representations of the (familiar) causes/effect concepts at each step was left on the blackboard, with simple arrows connecting the sequence (instead of the spoken argument). After that, the teams were asked to collaborate to answer the question "why is acid A stronger than B" with a *top-down explanatory-chain argument* (from the effect to be explained, backward to the causes). The argument-answers were then anonymously handed out to the other teams to count the number of explanation steps and to report possible errors. The anonymous answers were digitalized, prompted by the teacher and shared in a web document to the whole class for the sake of critically fixing the prompts.
f) in the most resistant-to-treatment cases of causative-explicative chain arguments, a complete sequence of shuffled subclaims was given with the task of reconstructing the right sequence. A similar task was to insert the missing connective words to complete the argument made of cause//effect pair of clauses. The linking words were to be created in one case, and to be taken from a list in the easiest case.

The kind of feedback given to the individual learners or teams, depended on the demand of revision of the spontaneously-constructed arguments and this was determined, in turn, on the large differences in the development of conceptual thinking and in the quality of the arguments that the students elaborated without assistance, at different ages. Therefore, it is worth reporting the most frequent demand of feedback in the two different classes (third grade, 16 year olds and fourth grade, 17-year-old students).

Most frequent demand of feedback in third grade
a) The meaning of some term was reported from Wikipedia instead of answering a very precise question (the focus question was not considered in its detailed meaning, but as a "hint to talk generally and freely of a certain subject").
b) "False claims": list of non-predicating concepts or data are given instead of knowledge claims or assertions.
c) Lack of analysis: an answer is given as a single undivided block of text.
d) Lack of coherence: isolated blocks of information about some scientific terms, with mixed expository, descriptive or expressive texts.
e) Causes are mistaken with effects and other logical inversions
Just one real example among many: "Dichloromethane molecules are more polar because dichloromethane is the most water soluble of three liquids" = a consequence has been put forward instead of a more profound cause.
f) The same phenomenon to be explained, or an equivalent one, is adopted as an explanation.
These are just three real examples, taken from dozens. a) Focus question: "why is water a so polar solvent and capable to dissolve salt?" Single line answer: "because water is highly polar" (no comment necessary); b) "What explains why the retarding potential which stops the photoelectrons does not change if light intensity is increased, is precisely the fact that light intensity does not affect the energy of the emitted electrons." The explanation sentence is equivalent, as a relationship between *facts,* to the phenomenon to be explained that was stated in the first clause. It lacks any *theoretical* aspect connected with the nature of light, which should have been adopted as an explanation, but was owned by the student as *inert knowledge*; c) an answer by a three-student team: " In our experiment we have seen that dichloromethane is the most soluble of the three liquid chloromethanes, *because* its solubility amounts to 13 g/L > 8 g/L > 0,8 g/L" (the fact is happily explained by the fact itself, with scientific aplomb!)
g) A false connection with a true claim is adopted as a warrant
Example focus question: "Why does your textbook consider ionic bond not really a bond at all?" True Argument: Textbook says that ionic bond is not a true bond because that bond is just a union of two elements with opposite charges. I think, on the contrary, that that is a true bond because it permits to the two elements to obtain stable configurations. Thus, it's a mistake to say ionic aren't quite true bonds."
This is a good example of arguing, but the student considered the stable configuration as essential in bonds, instead of taking into account more concrete features as the capability of the "elements" of sticking to each other, determining a stable composition.

Sometimes clarification issues have been made after the analysis of the misconceptions in the protocol outcomes, with poor, if any immediate results. An example is given here of point *e)*, about the concept of *evidence* as a link between theoretical-hypothetical and factual claims:

Clarification 1 [Teacher]: "Not everybody grasped the asymmetric relations":

"Evidential Element [redacted] *Hypothesized Crime";*
"Change in Observed Properties [redacted] *is an evidence of* → *Structural Change";*

These claims are right. But you cannot say, as somebody did, that those claims are equally correct:

"Structure Change [redacted] *is an evidence of* → *Change in Observed Properties";*
"Hypothesized Crime [redacted] *proves* → *Evidence of Crime".*

The existing structure of generalization of pseudo-concepts is still dominant and this prevents the youngest adolescents from voluntarily and autonomously working out a difference in the hierarchy of concepts, or distinguishing what is factual from what is theoretical, when these concepts as "structural change" and "observed properties", are not immediately objective or familiar, thus making whichever relation between them equally allowable. Nevertheless, these distinctions can be made thanks to the assistance of teacher-mediation, leading *in the long term* to the development of autonomous conceptual thinking. What should be absolutely avoided is to believe that if the learner utters or writes the same terms that correspond to the scientific concepts of the teacher, in spoken, written language or concept maps, then that learner has a conceptual understanding.

Fourth grade. The most frequent feedbacks were to...
a) signal the need for explaining the meaning of a concept by means of a claim;
b) signal the lack of a connecting link (a concept or a knowledge claim);
c) propose a change in the knowledge claims' sequence to keep closer the most interrelated concepts or sub-arguments;
d) establish a connection, a comparison, a causal link, etc., between two or more claims;
e) going back more often to the focus question, to re-evaluate the whole argument or an overlooked aspect of it;
f) split a complex knowledge claim into simpler ones, giving also a criterion if needed;
g) advise a change in the division of claims, by means of a different criterion of using a hierarchy of concepts or a new general concept;
h) review one particularly weak part of the argument.

It can be appreciated that these interventions were always to adjust a regular process, but *never* to make the task simply feasible, or understood, as it was needed in the third grade class.

5 Collaboration and application examples

The written & collaborative argumentation activity was originally planned as an extension of the advanced ALCA protocol (Academic Language of Chemistry for All, Tifi, 2013), a protocol that was derived from Mahn's ALA protocol (Mahn, 2014) as suggested by the many similarities between the task of extending the ZPD of adolescent learners of a second language and that of adolescent learners of scientific literacy and of language of chemistry. The protocol was to support the mastery of systems of general-abstract concepts that were emerging during the laboratory study-of-cases activities, but in the second part of the year it was adapted to empower conceptual thinking and reflection about topics that were theoretical from the beginning. The following plan was devised to maximize individual reflection, face-to-face interaction and peer discussion, and was applied several times, until the students mastered and appreciated the rubric to rank the others' arguments - presentations.

Starting from a specific focus question as prompt,

1. At home. In a Google document, capture individual ideas and concepts in numbered short sentences, and share them with the teacher;

2. At home. The teacher collects groups of four answers in single documents and extends the sharing of the four partially structured answers to student pairs for next step. Every two students review their own answers, together with the answers of two anonymous teammates.

3. At school. The two pairs of every group of four are reunited to work in a document with the reciprocal revisions, original answers and concept lists. Then, they have to reduce to the minimal essence the single agreed argument-answer that will be presented to the class;

Before the next turn, the teacher checks that every peer group correctly isolated the concepts that will be used in the answers, and prepares a table of these concepts of all groups, inviting them to edit their own concept lists, and to prepare the speech to defend their answer (step 4).

4. At school. The table of concepts that have been used by each peer group is showed and compared, while each group tells the class from memory how they answered the focus question, and then they defended their view by answering the questions that the other groups asked within a limited time. The knowledge of concept meanings can also be checked by the questioners. At the end of each presentation, the answer and conceptual knowledge are rated by an objective scale:

5 pts: the answer doesn't need any change or implementation; any objection have been rejected with grounded motivation
4 pts: the answer and concepts were questioned, but the presenters were able to adjust and adapt it at the moment
3 pts: the answer was challenged and the group replied to it, but it still seems that something should be changed or reviewed
2 pts: the answer was subjected to criticisms and the defenders overtly need more time to reflect on it and adapt it
1 pt: the answer was judged incorrect in some fundamental points, but the defenders don't accept-recognize that corrections are necessary
0 pts: The answer (concepts included) is completely or partially missing

the rating is agreed within each peer group, and then assigned in a overt poll.

5. At home. The best rated structured-answer & related concepts are shared in the four peer group documents and each peer group is called to edit their own as turned out in the presentation step and then to transform it in an argumentative sequence and as a Cmap.

The following is a teacher's report of one application of the protocol to the general task of "what determine the identity of a substance", after several experimental cases were studied.

"What happened during the first 4 steps is that the teacher himself became more aware of the structure of the system; some useful concepts emerged, as 'chemical behavior'. This simple realization helped to put other measurable physical properties (e.g. b.p., m.p., refractive index etc.) in the correct scheme or cmap of characterization of a substance. All these concepts could be collected under the new root concept of 'characterization' of a chemical substance, comprehending composition, structure, physical properties, chemical behavior. This augmented awareness of the teacher a) is part of the constructivist game of creating a 'local' academic language, starting from the students everyday language, b) it can be transferred to the students, and this corresponds to extending their ZPD and, c) it leaves a higher level of know-how and deeper understanding to the teacher too. These three points demonstrate that in the ALCA protocol the intervention of teacher in helping the construction-reviewing of the answers or challenging the most 'dangerous' misconceptions is a very important element of the process."

The following concept map was made by one team in a related activity about 'evidences of chemical reactions'.

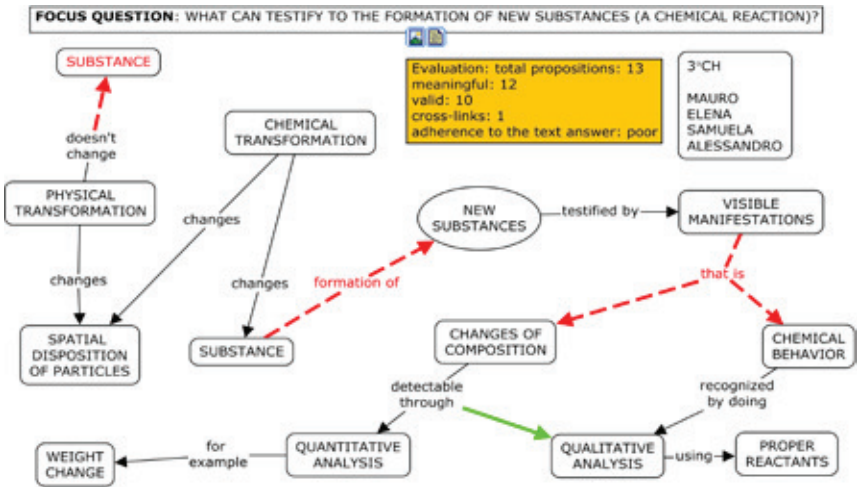

Figure 1: Concept map constructed by a team after the protocol ALCA. The correct idea that changes of composition could be revealed by qualitative analysis was considered a "happy" cross link because it demonstrated a newborn concept-association. "Adherence to the text answer" is a rough indication of the correspondence between the answer as written argument and the corresponding cmap.

Would the students learn abstractedly a pre-made scheme, maybe they would have got a better mastery of the scheme's words, but not of how to use these words to make sense of real-world instances and to re-evoke their previous experience. We can adopt "concept shaping" in referring to mental processes for conceptual change, differentiation and adaptation, as different from "concept mapping" intended as a process of externalization of pre-existing conceptions. The two are diverse only on a quantitative basis. Concept mapping on paper or screen, as well as construction of written and shared arguments, is not only 'for others', as much as concept shaping in the mind is not only 'for oneself'. The two are both for creating new concepts as well as for raising awareness of old concepts. Both are not completely transparent and conscious processes. Concept mapping and written argumentation are more likely to be authentically transparent (i.e. to constitute a representation of the system of concepts of the learner and of the terms and concepts that he would really use spontaneously in other contexts), if they have been preceded by some activity that socially triggered "concept shaping". This is just another way to consider the interaction between internal and external discourse that has been mentioned in the 2nd paragraph.

A different protocol was adopted for a shorter activity on the chemical bond.

Individual Phase (every member of the team choose a different focus question)

1.1 Read paragraphs 1.2 and 1.2 at page. 3, 4, 5 of the textbook (Organic Chemistry) and then read the focus question.
1.2 Select the useful and pertinent parts of the text
1.3.a Write the answer as short knowledge claims of 1-2 lines to set a context that is useful for the focus question.
1.3.b Add more knowledge claims chained and numbered in a logic way, to complete the development of argument
1.3 c Select the concepts of first and second level that will be useful in the construction of a concept map.

Group phase

Collaborate in the construction of the Cmap within the teams which dealt with the same focus question (*Cmap hyperlinks in parentheses*)
1) Why is the formula of lithium sulfide Li_2S? (*http://goo.gl/LHPbgb*)
2) Why does your textbook consider ionic bond not properly a chemical bond? (*http://goo.gl/3B5Ykf*)
3) Why is the carbon disulfide liquid and why its water solution hasn't an increased electrical conductivity? (*http://goo.gl/g2Cxoo*)

The concept maps retain some interesting features from the derived arguments, showing that some connecting words can be implemented (demonstrate, therefore, because, consequently, for the sake of, thus) in the cmaps.

The last case of the year studied experimentally the reaction of limonene with bromine; it was preceded by a theoretic study of the general mechanism of electrophilic addition to alkenes, with the following plan.

1. At school, the teams answer a quick questionnaire to contextualize the argumentation topic, and then start to answer the following focus question: "*How does the reaction mechanism of the electrophilic addition to alkenes explain Markovnikov's Rule?*"
2. The teams' arguments are given feedback by the teacher and edited until satisfactory. Then concepts are highlighted, ready for the cmap.
3. concept maps are made individually on the basis of the team argument.
4. Pros & cons of some arguments and cmaps are analyzed and discussed in the class.

This activity resulted in interesting insights because the two parts of the focus question were easily attainable if set apart, but the conjunction of the first part (reaction mechanism) as a causal explanation of the

second (Markovnikov rule) was hard to put in words, whether in the phase of constructing the argument or in the concept mapping individual activity. A complete argument and derived concept maps are shown in closure.

Team B answer-argument (first level concepts are double underscored, second level are single underscored; connecting words are in bold type).

1. The alkene is attacked first by the electrophile part of the reactant, in the mechanism, **because** it is a nucleophilic substrate.
2. One bonding pair in the double bond is used to covalently tie the electrophile to one of the two carbons; **consequently** the other carbon becomes positive, as part of a extremely reactive species (**because** the positive carbon doesn't reach the octet), called carbocation.
3. Among the different possible unstable carbocations, is lower in enthalpy the more substituted one, **therefore** the effective impact between alkene and electrophile will require less energy if the most substituted carbocation will be formed as an intermediate.
4. Thus a lower energy barrier to overcome would **imply** a decidedly higher rate of conversion when the reaction passes through the most substituted carbocation.
5. The most substituted intermediate carbocation is the only formed in significant amount, **therefore** the nucleophilic part of the reactant will be bonded to the most substituted carbon, as the Markovnikov rule established.

The Cmaps by E.C. (*http://goo.gl/WRwhDY*), more tied to the sequential structure of the reaction mechanism in the argument, and by A.Z. (*http://goo.gl/NY9dx1*), with more descriptive content, have been translated. Every individual concept map was reviewed by the teacher and discussed individually with the students, or in interactive discussions in class. Several students made new versions with less errors, after the revision.

6 Conclusions

The greatest effort in this first part of the experiment was devoted to the development of a series of strategies to implement and evaluate the construction of written argumentations as a *generalized* form of mapping concepts and transforming complex meanings (*concept shaping*). Therefore, the training and scaffolding of concept mapping was somewhat sacrificed, although many concept maps were skillfully constructed by individual students, groups and stable teams, sometimes with noticeable quality and effectiveness. The structured argumentation activity was thought from the very beginning as something to be coupled to concept mapping; more ideas about the way of coupling emerged along the way.

A possible next step in this research, would be to highlight concepts in the written argument primarily as a way to augment awareness of the concepts and their role and differences, and to favor the cognitive functions of disembedding and generalizing, leaving the students free to adopt and adapt or not the same concepts in making the cmap, as well as to add more examples and different resources.

The further contributions to the extension of ZPD, to the development of thinking in concepts and of meaningful learning, that is expected by the concept mapping process, will strictly depend on the system of activity which is entailed in the learner-cmapper process (Aguilar Tamayo, 2006). This system is in turn "prepared" and empowered by collaborative and teacher-mediated construction of another kind of textual artifact, which has been called 'structured argument' in this exploratory research.

While concept mapping can be considered as a sort of crowning activity, and an integration of multiple pathways and tools to operate a further synthesis in the *final* part of the learning process, it manifests a limit in reflecting and accompanying the "work in progress" of conceptual development, because of its excessive distance from the inner and external discourse, and because of its "syntactic hindrance".

These limits can be balanced by alternative *propositional* artifacts, based on knowledge claims that are more flexible and suitable for the *core process* of conceptualization.

Whereas the written arguments are destined to subside once they have performed their function of driving disembedded thinking, objectifying ideas, and stimulating reflection, the role of concept maps remains undisputed as supporting a synthetic portfolio of competencies, intended as a set of retrievable conceptual structures which the learner has mastered and can be able to master again.

The integration of the individual and collaborative activity in the combined proposal, on the other hand, warrants a high degree of sharing and inter-subjectivity of such competencies. In this respect, the cmaps edited by the students and teacher can be a profitable and further source of stimuli to the sharing of competencies.

7 Acknowledgements

The author is thankful to Holbrook Mahn and Manuel Aguilar Tamayo for their friendly, thoughtful and professional advice.

Referencess

Aguilar Tamayo, M. F. (2006) El mapa conceptual y la teoría sociocultural. En: Cañas, A. J. y Novak, J. D. (ed.) Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping 2006. Vol. 1. Universidad de Costa Rica.

Baddeley, A.D. (2002). Is working memory still working, European Psychologist, 7(2), 85-97.

Donaldson M. (1987) Children's Minds,W W Norton & Company Inc., 1979

Donaldson M. (1987) Human Minds, Penguin Books, 1992

Mahn, H. (2014, in press). Classroom discourse and interaction in the Zone of Proximal Development. The Handbook of Classroom Discourse and Interaction. Oxford, UK: Wiley-Blackwell

Mahn, H. (2012) Vygotsky's Analysis of Children's Meaning Making Processes. Downloadable from IJEP: www.hipatiapress.info/hpjournals/index.php/ijep/article/view/289 (Last check 26/05/2014)

Tifi, A. (2013) Approccio al linguaggio chimico attraverso lo studio dei casi. Parti I/II. XVIII Conferenza Didattica della chimica, Naples October, 12nd 2013.

Vygotsky, L.S. (1986) Thought and Language. Revised and edited by Alex Kozulin. Massachusetts, U.S.A.: M.I.T.

Vygotsky, L. S., (1998) The Collected Works of L. S. Vygotsky: Child Psychology, Chapter 6, The Problem of Age. Plenum Press, New York