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CROSSWORDS SUPPORTING CONCEPT MAPPING LEARNING

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Abstract. This paper reports a preliminary experiment on a propaedeutic and supporting activity for *Concept Mapping*, based on concept definitions and discovery relations among concepts. The *CrossWord Making* and *Solving* can be accomplished in several ways that proved to be challenging and meaningful within a group of nine students were it was tested extensively to enhance the *Concept Mapping*. Crossword making implies clues construction, which represents the key stage of our project. This job is similar to making a *Knowledge Soup*, as it represents an opportunity for the metacognition process development. *Crossword* making at school can be promoted as an autonomous pathway, with its own criteria different from the usual crossword puzzles; nevertheless many objectives are shared with concept mapping. Best results, both in terms of insight/cognitive empowerment, and in terms of students' preferences have been achieved by preparing the Concept Mapping through crossword making/solving. This project has proved to be effective and affordable with minimum requirements (a software for cross making). Furthermore formative evaluation would be deeply inherent within the process.

1 Introduction

Mastering of concepts may be scored in a taxonomic scale, as that one in table 1. Elio Damiano (1994) suggests that every instructional tool ought to be evaluated according to his own taxonomy.

Table 1. Damiano's taxonomic sequence for guessing expected performances in tackling a learning unit or tool

I	– Recognition of a concept from a specific event or object (Generalization)
II	– Elicitation of attributes that can define a concept (Definition)
III	– Discrimination of pertinent elements from those that are not related to a specific concept (Discrimination)
IV	– Application of that concept in problem solving (Application)
V	– Application of a concept in a different context within the same discipline (Internal transfer)
VI	– Application of a concept to common sense or to personal experience (Wide transfer)
VII	– Transferring of a concept in a metaphoric or figurative context, and preserving - at the same time - awareness of the border line within the logical domain of application (Analogical transfer)
VIII	– Expressing judgment on correctness of concept application in a given context, by discussing the reasons of this evaluation (Meta-conceptual competence)

As an educational tool, the crossword puzzling can be used to assess the first three levels in this taxonomy. Concept mapping in school education and the construction of definitions clues, can even reach the fifth grade. A well devised and planned educational course, based on problem solving activities, or liberal and individual practised expressions of arts and professions, can grant whole levels of concept mastering. Despite first grade actually represents the lowest level of the taxonomy, it is a very crucial one. The ability of recognizing a concept, while "watching" an exemplar of it, is the minimal warranty for a meaningful assimilation of that concept. Very often the most advanced and successful transmissive teaching methodology cannot grant that level at all. In fact if - after a science lab activity on repeated measurements of volumes and masses aimed to "show" or "demonstrate" density concept- students are asked why one cubic centimetre of copper weights almost nine grams, it is exceedingly likely they either remain silent, or will come out with the expression "heavy!", instead of *density*. Actually if students learn a concept through a mechanical or "empty vase" teaching method, they would never figured that concept out!

What is the link with concept mapping? If students are not able to elicit a concept, it is very unlikely they would write it down to construct a concept map around it. Therefore crossword making, crossing and recognizing concepts, are feasible tools that enable students to be familiar with new concepts and their relative meanings. These tools also help discover new domains to be mapped, thus achieving meaningful learning, "stainless" to time action (Novak, J. D., & Gowin, D. B. (1984)).

2 Building up the sequence

At first teachers and students enjoyed the crossword making (teacher) and the puzzling (students), by using free software for making crosswords, JCross, application of “Hotpotatoes” (http://web.uvic.ca/hrd/hotpot/).

Both in the first experiments, and in the next ones we would realize that every context or domain of chemical knowledge, from aliphatic hydrocarbons up to genetics basics, could be entirely fixed in about twenty keywords and could be regarded as main concept. It was also clear that clues could be constructed as multiple propositions, by deriving the concepts from the same sub-domain or from the upper domains of the subject (physical chemistry in this case). These lists of propositions or definitions can be regarded as knowledge soups, like the ones proposed by the teacher as an asynchronous scaffolding for concept map construction (Cañas et al. (2001)) and cmap.coginst.uwf.edu/docs/soup.html

After these early experimentations we focused our attention on a more effective learning process, where couples of students would make a crossword, define its clues, and puzzle with it. Poor results were achieved when students were given the task of constructing definitions (providing them with a set of terms and concepts). We had underestimated:

1. how the limited confidence with the new concepts compelled them to search meaningless definitions;
2. that the students didn’t share the same reasons and foresight as ours to fulfill that activity. They were rather interested in completing the crossword and puzzling themselves or their peers with it.

On the whole this “free style” definitions construction activity was of no help to design better conceptual maps. Therefore we examined the inadequacies of clues made by students and we studied guide lines which could help the students give more meaningful definitions. The solution of this problem is shown in the next paragraph.

The next step was the exchange of crosswords among students. Each student puzzled him/herself by solving the cross of another student. The crosswords were online in the web page of the class.

After specific lessons and lab. activities on the matter, couple of students had a session of concept mapping on the same domain of crosswords. They received an ab-initio or skeleton cmap, with only three – four first level concepts, linked to the main concept. Each student or couple had their list of crossword clues of all key concepts of the domain, (a useful knowledge source). Nevertheless the students could use other concepts and examples not included in the crosswords. This stage was accomplished in two educational modules during the final school term.

These concept maps were very refined; nevertheless we hadn’t any cmap to be compared with, on the same domains faced without crossword making. Positive evaluation from students was beyond the whole process and feedback. Concept maps of this project are linked from http://win2ks.divini.net/chimica or from http://www.divini.net/chimica/ARCHIVIO%20IVCH%2003_04/IV_CH_2003_04.htm

3 Critical exam of student’s concept definitions - evaluation

The definitions editing, is submitted to several criteria that are not mastered by students at all. Those criteria are different from those of the puzzling magazines, since we want to get to the subject knowledge meaningfully. In fact teachers’ definitions take into account:

1. The use of conceptual meaning to define objects or events
2. Define terms from the closer context where they are learned or applied, using also cross links to the main concepts of that knowledge domain.
3. Avoid trivial words associations by using more inclusive categories to get to a concept.

Conversely, early definitions constructed by students, were often based on subsidiary aspects of events or objects. They were also made of concepts derived from not inherent contexts, usually made of less inclusive concepts or specific exemplars of the concepts to define. Moreover they had difficulties to focus and evaluate more than one possible definition. Eventually teachers could optimize the “distance” between definitions and concepts, according to the students’ level, within the Vygotsky’s Zone of Proximal Development, while students often proposed far easier or harder clues.

Most rules were fixed out of a critical examination of students definition-clues (Table 2).

Table 2 Classification of the most common causes of not acceptance of crossword terms and definition clues made by students

#	ET	Error Type	Detailed	Examples
1	WST	Wrong Spelling of Term	Wrong spelling of the term	e.g.: **NERST** instead of NERNST
2	RPT	Repeated Term	The term to be defined, or a part of it, is contained in the definition too.	e.g.: ISOELECTRIC**POINT** = "***point*** *where (+) and (-) charges are balanced*"
3	WCT	Wrong Choice of Term	The less specifying attribute in a compound term is chosen as the term to be defined.	e.g.: **RAPIDITY** in response (of a probe) instead of the term RESPONSE
4	WD	Wrong Definition	Definition is simply false if referred to that term.	e.g.: POTENTIOMETER = device for measuring **power**.
5	SWC	Sentence Without Clue	Assertion doesn't lead to any term to find.	e.g.: NOBLE = *platinum is one of most expensive metals in the world*
6	OCD	Out of Context Definition	Definition relies in the same general science subject but does not use relations of that term with other concepts of its context	e.g.: LITHIUM = *first metal in the table of the elements* instead of *migrant ion in a special glass membrane for pH probe*
7	WC	Wrong Context	Improper context use for that term or concept	e.g.: MEMBRANE (a glass component in pH probe) = *a kind of* ***pump***
8	CSD	Common Sense Definition	Definition based on common sense-meaning instead of scientific one.	e.g.: SATURATED (of a filling solution for electrodes) = *synonym of* ***full***
9	PSD	Poor Sharpness of Definition	Vague definition; insufficient data to infer crossword; too loose context.	e.g.: "*As can be a reaction*" e.g.: ROSS = "***electrode*** *with short response time*", instead of "*pH electrode that…*"
10	ND	Nested Definition	Some terms used in the definition have to be inferred from another definition	e.g.: "*law that gives potential of a device formed of two electrodes…*" instead of: "*law that gives potential of a cell*".
11	SCD	Sub Categorical definition	Concept defined from a particular example of it.	e.g.: CELL = "*named Daniell when a copper foil is soaked in a solution of* $CuSO_4$"

Table 2 labels and describes the most common errors, limitations and defects found in the students definition clues. Teachers would proofread and evaluate definitions, writing acronyms of table 2, then would return them to students for adjustments (students have a copy of table 2 with examples for a better understanding of errors). Students would re-write defective definitions (and terms to be defined, in a few circumstances). At last executable crosswords would be loaded in the website. Not only does the software help students to study the subject with fun, but it also supports concept mapping on the very subject. During the revision-evaluation process the mediation of the teachers is very important: students can reason over meanings, can construct mini-cmaps (like "nested-nodes" in CmapTools) and place concepts in a proper context. Students would deal with metacognition too, meditating how other people have to think to recover terms from clues.

Errors of table 2 can be regarded as rules for making good (and meaningful) definitions. Some of them coincide with rules used in concept mapping. For instance: the search for relations with other related concepts; never uses the same concept in two or more nodes; or defines a concept by relating it to more inclusive concepts or attributes of the same hierarchical level, rather than specifying examples. Definitions would keep a denotative and connotative relation with the concept rather than an associative bond. So we should accept that some crosswords in the grid are repeated in other clues. Furthermore, making clues speeds up assimilation of key concepts of that knowledge domain, and increases awareness in the conceptual structure of the subject, meant as relations among domains, sub-domains and nested contexts. We hope that this induced contextualization would both develop students awareness of inclusive concept to chose, and make more meaningful concept maps. Figure 1 represents the complex and nested domains structure for every discipline, from an expert point of view. Students usually would manage only simpler structures. The elaboration of context type errors (some depicted) and the relative discussion, would drive students to draw sharper edges between domains.

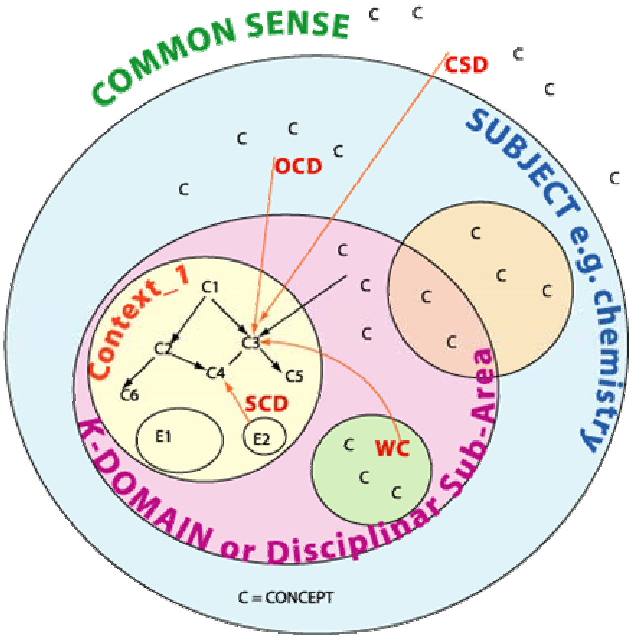

Figure 1. Expert structure of a discipline, as nested and contexts and domains. CSD, OCD, WC and SCD are referred to **Table 2**

4 Projects for the future

Within the process, the students' were made more responsible of selecting the words-set to be defined and crossed. Teachers could also evaluate the educational process in a deeper way. We should pay more attention to the connections among definitions and concepts in the crossword and structure of the related concept map.

5 Conclusions

Thanks to constructivist theory of Ausubel and Novak (and to the new technologies), understanding of the learning process has profoundly developed over the years. In the past, almost 90 per cent of teaching time was based on a lecture-frontal repetition of not requested, prefab and boring definitions, which were learnt mechanically, repeated on demand, and forgiven in a very short time. This project shows how the rate can be reversed, in such a way that most of the time is used by students for developing and constructing strong mental representations of relate-subjects materials that are both meaningful and easy assessed by the teacher. This reinforced background would help students face concept mapping in complex domains.

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