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On Fostering a Co-Creative Process within a CSCL Framework

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In this article is introduced a co-creative process fostered by a Collaborative Learning Framework which pursues to engage peers of students in a synchronous collaborative dynamic to build the knowledge by representing it by a formal digraph called Networks of Concepts (NoC). This digraph, the NoC, allows building and representing the knowledge in a synthetic way, while the co-creative process aims at developing cognitive skills and collaborative attitudes as essential part of 21st century skills for students. Nowadays, the Collaborative Learning Framework has been and is currently being used in Mexican universities in different undergraduate programs such as Industrial Engineering, Computer Science, Sociology, Accounting, Business Administration, and Molecular Biology; in this article we analyze and discuss a particular case of an example in the Engineering program. Thus, the analyzed digraphs are the outcome of a co-creative process that is carried out through synchronous-mode argumentation and shared interactions by peers of students.

Keywords: Co-Creative Process; CSCL; Network of Concepts; Cognitive Skills

Introduction

Nowadays, Mexican universities, as many others abroad, are concerned with applying models that allow them to improve learning processes; consequently, one significant change is the student-centered learning approach instead of the teacher-centered learning approach. However, the student-centered learning approach requires that students develop several skills that allow them not only to learn new topics but also to apply previously learned knowledge to find solutions to real problems in a cyclic way throughout their whole lifes. According to our experience, a basic set of cognitive skills that could allow students to become lifelong learners is composed of analysis, synthesis, abstraction, structuring among some of the most important (Ramos-Quintana, Sámano-Galindo, & Zárate-Silva, 2008). Additionally, we consider social skills like communicating, interacting and collaborating, all of them essentials in the 21st century Education paradigm.

Thus, to foster these skills, we have created a Collaborative Learning Framework (CLF) composed by the stages of reinforcement, acquisition and assessment of knowledge, as shown in **Figure 1**. The reinforcement stage aims at emphasizing knowledge that has been acquired previously as a part of a course. The acquisition stage aims at promoting the responsibility of the students of their own learning by dealing with Ill Structured Problem (ISP) (Jonassen, 1997). Finally, the assessment stage looks for creating self-consciousness of performance achieved by means of a peer-review process. However, what makes this framework accessible and more attractive to students and teachers is that it fosters and encourages skills by a co-creative process mediated by computers.

The Collaborative Learning Framework

The Collaborative Learning Framework is inspired in social-constructivism (Vygotsky, 1978), problem-based learning (Barrows, 1985; Barrows & Tamblyn, 1980; Koschman, Feltovich, Myers, & Barrows, 1992), self-directed learning (Garrison, 1992; Gibbons, 2002), and collaborative learning (Dillenbourg, Baker, Blaye, & O'Malley, 1996; Dillenbourg, 1999) theories to integrate a proposal that pursues fostering cognitive skills. Because of them, the framework outcomes in our CLF are not the result of an individual but two individuals that by social interactions (Goodsell, Maher, Tinto, Leigh, & MacGregor, 1992) write and exchange messages and sharea space to co-construct creatively an agreed Network of Concepts (NoC); such consensus is supported by a totally-ordered sequence of messages that represents a dialog with a precise goal: to reinforce knowledge previously learned or acquire new knowledge and assess it. Thus, both dialogs and NoC are outcomes that can become the object of further analysis and evaluation by teachers. Network of Concepts is the name that we assign to a directed graph (digraph) that represents the

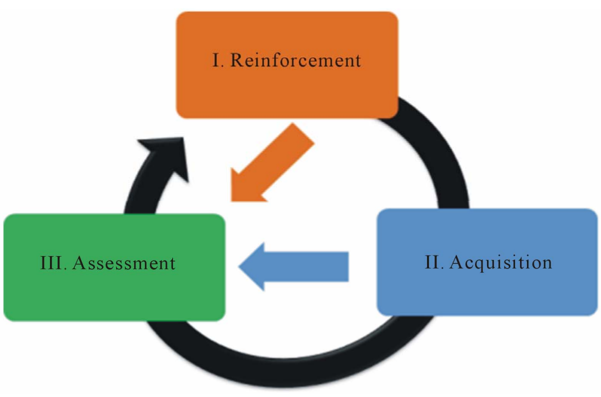


Figure 1.
The general stages in the Collaborative Learning Framework (CLF).

knowledge being reinforced, acquired or assessed, which are the main tread of this article. **Figures 8** and **9**, in the appendix section, are both examples of full Network of Concepts created by students.

This framework as an instructional strategy, on the one hand, deals with Problem Based Learning (PBL) because its intrinsic capacities for the development of Self-Directed Learning (SDL) and because of their potential to develop cognitive skills during the process of solving the involved problems. On the other hand, the CLF deals also with Network of Concepts, which among its characteristics has a bottom-up methodology that allows systematically, integrate and develop cognitive skills during the building process. Such methodology is introduced later.

Thus, to foster self-directed learners with their associated skills to be developed, we provide them with appropriate scenarios with which they become familiarized concerning the strategies proposed as well as the guidance of the teacher, who is responsible for defining the topics to be reinforced, acquired or assessed by following either or not in a sequential way the stages shown in **Figure 1**. In spite of the fact that the stages of the CLF should be performed sequentially, from stage I to stage III, it is possible to insert the assessment stage once reinforcement has been applied. If such is the case, the teacher decides whether the student promotes the peer-review process on an early stage.

Description of Stages and Activities within the CLF

We attempted to build the CLF as simple as possible, then during our exploratory steps we found that trying to learn new topics and build network of concepts at the same time could be disappointing for most of the students. Therefore, it is very important considering how they feel with respect to the process, as Shaw points (Shaw, 1991), for that reason we introduced the reinforcement stage allowing students to become familiar with the methodology to build Network of Concepts, as well as with the computer tools, at the time they could reduce cognitive load by exploring a topic previously seen.

Thus, reinforcement stage allows practicing how to use previously-learned knowledge by summarizing a topic previously seen under a representation of a Network of Concepts (NoC), where two students build co-creatively such NoC in a shared space through written argumentations in a chat tool. By working in teams, students get help from each other by recalling and building concepts together. Eventually, they can learn to negotiate their positions and common understandings. At this stage, it is expected that a facilitator will intervene to give them feedback about the work being done.

The second stage allows students to demonstrate the understanding of a new topic by converting the statement of an Ill Structured Problem (ISP) (Goel, 1992), which was provided by a facilitator, into a clear or well structure problem (WSP) (Jonassen, 1997). The gap between the ISP and the WSP represents the knowledge to be learned. So, an ISP is provided as a starter containing vaguely key underlying concepts and relations between them that form part of the topic. The students should seek to complete the rest of the concepts and to build relationships between them until they have achieved a complete structure that represents synthetically the knowledge of the topic. The proof that students have reached a higher level of knowledge is when they are capable of converting the statement associated with the Ill Structured Problem into a Well Structured Problem. During this process a set of cognitive skills such as those mentioned before is elicited (Ramos-Quintana, Sámano-Galindo, & Zárate-Silva, 2008). Thus, students should reach new knowledge by undertaking any activity that leads to the solution; meanwhile, the teacher facilitates the process by giving his/her point of view.

The third stage looks at stimulating argumentative dialogs between students by questioning the completeness of a Network of Concepts. To guide the discussion, teachers can provide students with a checklist similar to that used in Formal Technical Reviews (FTR) (Pressman, 2002). It is important to note that this stage does not include assigning a grade, but rather a critic of the work by another dyad and later a self-critic of the team's own work demonstrating acquired experience. Thus, dyads do not evaluate their own Network of Concepts but they do evaluate the work of another dyad; later, all dyads receive comments about their work and then they can decide to make changes to their work or simply dismiss these comments.

The overall activities implied in the framework are shown in **Figure 2**, and explained herein:

1) Decide the initial statement, as we imply, is a teacher's task since he/she decided the topic according to the specific activity of reinforcement or acquisition of knowledge.

2) Listing underlying concepts is a student's activity since after performing some recall/analysis he/she can list the underlying concepts. It is important to mention that this activity is carried-out individually by students.

3) Making relationships is an activity that is carried-out by teams or dyads, because through the exchange of messages they try to make an agreement about the assembling. Particularly this process conveys the synthesis action because duplicate concepts can be drop off. In addition, the task of creating significant relationships can be very challenge, as explained later in section *Building Network of Concepts*.

4) Building the network is the activity where semantic units are assembled to produce an abstraction of the topic. It requires structuring such units that make sense, as an example of this semantic unit see **Figure 3(b)**.

5) Reviewing the network is an activity that can be made by students or teachers; in any case, the review can provide a feedback about the possible corrective actions or general suggestions about the correctness or completeness of the network.

6) Questioning is the activity to appreciate or judge the comments given by others in order to decide if these are valuable and accurate or just desert to dismiss it, as a result it could produce a restructuring on the network.

Therefore, the overall activities are encompassed by a set of cognitive skills to be developed and which are showed in dashed rectangles over each stage. In the following section, we talk about the process to build a NoC and some aspects about the co-creative process are exposed.

Building Network of Concepts

The Network of Concepts is a directed bipartite graph, borrowed from Petri Nets notation (Diaz, 2009). Petri Nets are a mathematical formalism that allows modeling concurrent system, which with further analysis can provide with information about structure and dynamic behavior (Peterson, 1981). Their notation defines the use of two types of nodes represented by circles (called places) and rectangles (called transitions), then this nodes are joined by directed links (called arcs). In our

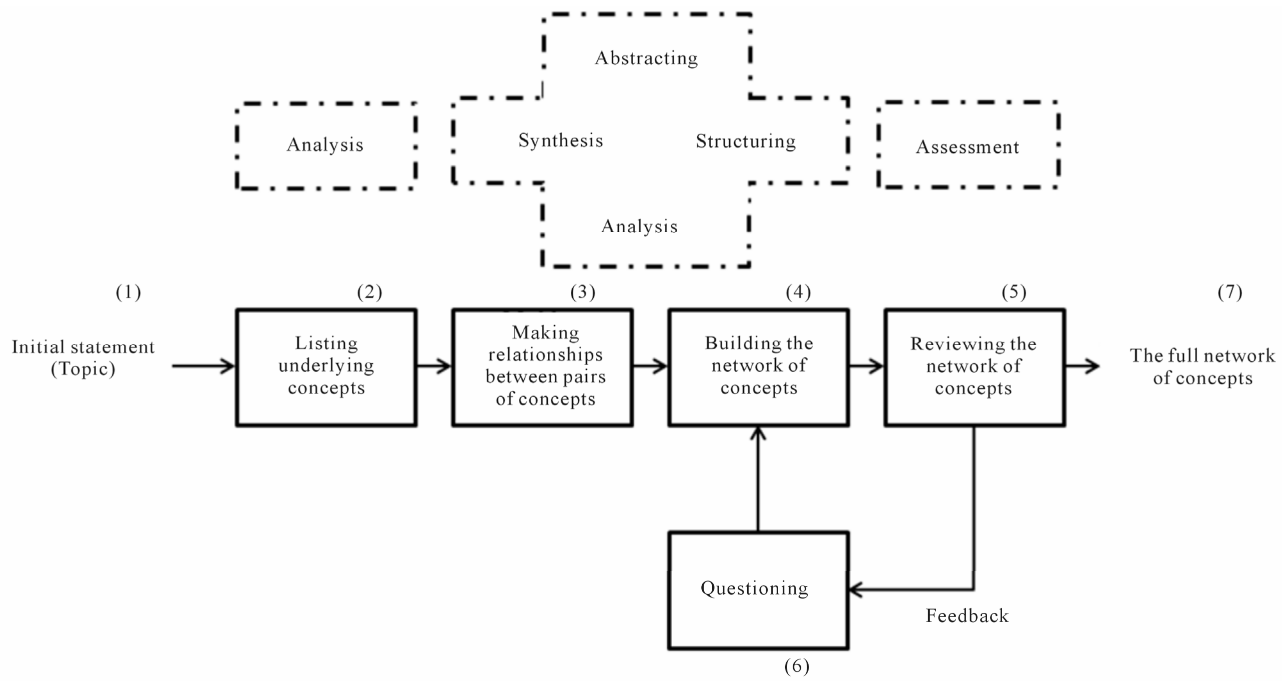


Figure 2.
The overall activities carried-out by participants in the framework are denoted by the directed chart; over each activity there is a dashed rectangle that reflects the current skill being used.

notation, circles are used to denote concepts; rectangles are used to denote meaningful relationships which are used to semantically provide a link between concepts. Finally, directed links are used to create a physical connection between concepts and in this way create semantic units. Thereby, several interconnected semantic units form a NoC. Graphically the **Figure 3**, reading from bottom to up denotes such steps. In **Figure 3(c)**, we have concepts and relationship scattered, In **Figure 3(b)**, we have created semantics units, and in **Figure 3(a)**, we have a full/partial network of concept. Behind the formalism that sustains NoC's, what makes the process feasible to students and teachers is the fact that it is a socialized process where in any NoC is the creative result of not only one individual, but also of two individuals, who co-creatively build a model.

On the other hand, NoC's are different from other more common graph representations like Conceptual Maps (CM) (Ontoria Peña et al., 1992) mainly for the use of relationships as semantic operators, which are defined in our work either static or dynamic. Such distinction is denoted by coloring each rectangle as white or black respectively. Dynamic relationships imply "execution", "processing" or "transforming actions"; this means that a certain concept c_1 is transformed into a concept c_2 through a dynamic relationship r_1, as expressed by the rule (1) shown below.

$$(c_1)\ \text{tadpole} \rightarrow (r_1)\ \text{metamorphosis} \rightarrow (c_2)\ \text{frog} \qquad (1)$$

Semantically we could understand this rule as: if a tadpole undergoes a metamorphosis, then it will be transformed into a frog.

Meanwhile, static relationships denote some reference or characteristic to another concept that does not imply a transformation. For example, it can be used to stay the fact that "the sun is a star", such representation is straightforward.

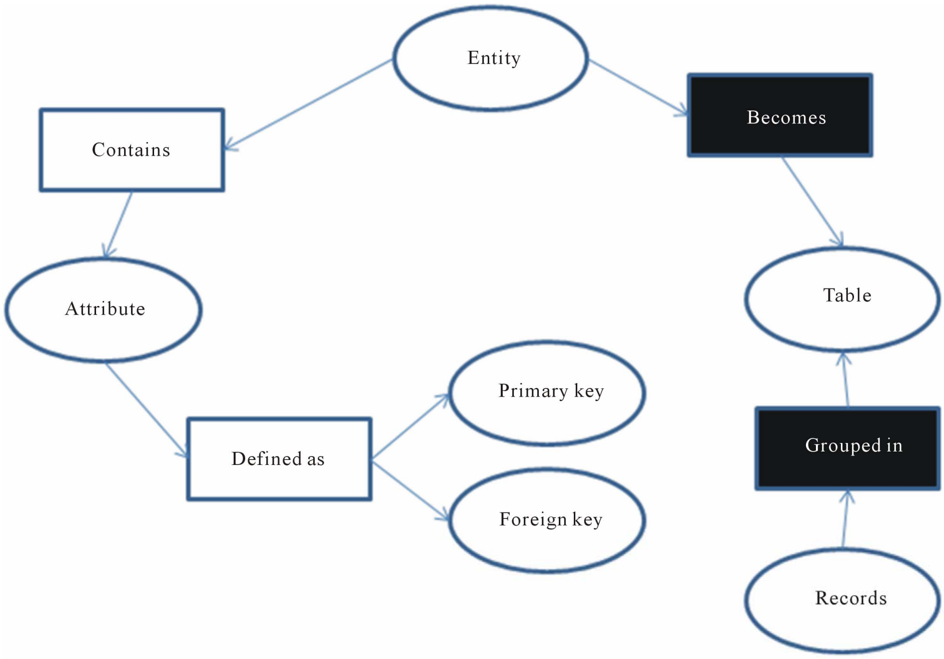
A Methodology for Building Networks of Concepts

The Network of Concepts is built by following a bottom-up methodology (Ramos-Quintana, Sámano-Galindo, & Zárate-Silva, 2008a), wherein, at the bottom level, students list a set of underlying concepts, at the next level, they link pairs of underlying concepts, and, at the top level, the whole Network of Concepts is assembled. During this process, students will need to analyze which underlying concepts are important so as to keep them in the shared space; later, they will need to create structures with semantic meaning as shown in rule (1). At the same time, they are synthesizing knowledge and an important exercise of analysis will allow them to link correctly the structures. As they move along, assembling the network, they create higher abstractions. Throughout this process, the argumentation is an important exercise to establish an adequate coordination between dyads.

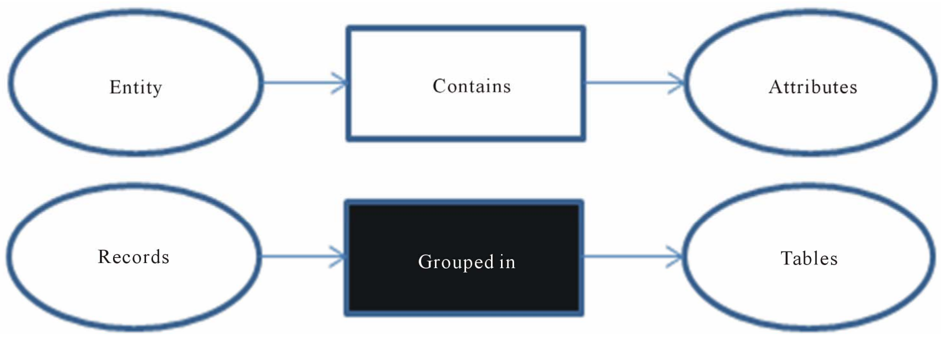
As a brief example of this process, we can see in **Figure 3** the building of a NoC from the bottom to the top level.

Mediation Tools for the Collaborative Learning Framework

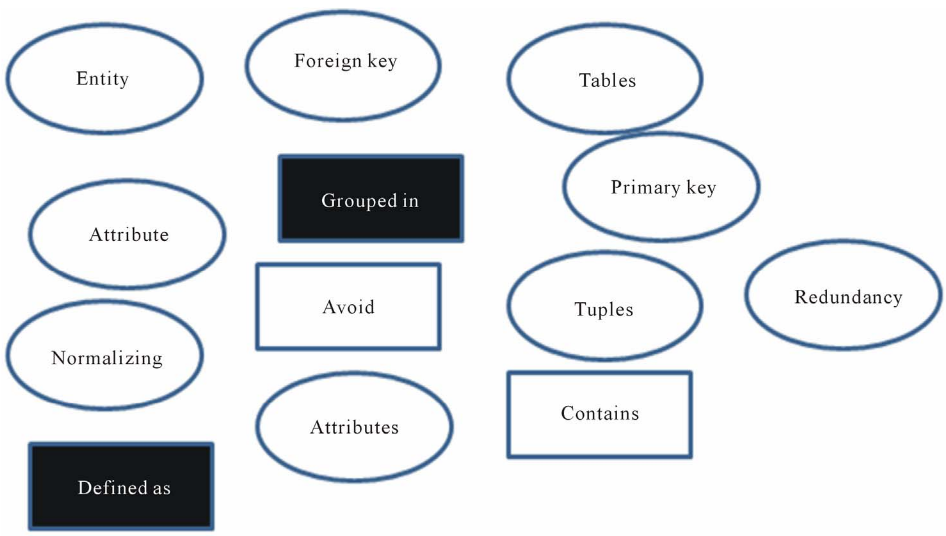
The Collaborative Learning Framework (CLF) was conceived as a synchronous-mode environment where students, distributed physically without face-to-face contact, work together to achieve a particular goal. For this reason, the uses of boards, forums or email are not suitable computational tools. Another idea was the use and interpretation of dialogs (the sequence of exchanged messages) to determine behavior patterns during the process of building the NoC's (Ramos-Quintana, Sámano-Galindo, & Zárate-Silva, 2008a; Ramos-Quintana, Sámano-Galindo, & Zárate-Silva, 2008b). Therefore the use of a chat is a suitable tool of communication. On the other hand, it



(a)



(b)



(c)

Figure 3.
Example of building a NoC at different levels of abstraction. (a) A full-assembled network of concepts at the top level; (b) Basic semantic units by related concepts in the middle level; (c) List of underlying concepts in the bottom level.

is necessary to have the possibility of drawing the network into a shared space where participants can observe and participate in the modifications; then a shared blackboard is an adequate tool to achieve this goal.

Nevertheless, the use of a piece of paper and face-to-face chat between peers can be a common practice to break the ice and introduce the methodology. Besides, when it is not possible to use technology, the Collaborative Learning Framework can go on during some sessions with this approach, but the benefits of registering and tracking process would not be achieved.

Technologically speaking, at the beginning, we used Freestyler (Giemza & Ziebarth, 2008) because it allowed us to keep a record of activities. However, this tool does not provide much control to the teacher; so students could interfere with other sessions and damage the creative process. Nonetheless, it is a good Java™-based tool, for some users present annoyances for configuring their IP address and plug-in. For that reason, we decided to create a Web-based prototype. This tool is called the Collaborative Distributed Tool (CDT) (Rojano-Caceres, Ramos-Quintana, & Garcia-Gaona, 2010) and it is a Rich Internet Application (RIA) that can be executed for any web browser that has the Flash© plug-in. Currently, it is available at *collaborativelearningframework.net*. In **Figure 4**, it is shown how a group of students interacts with each other by means of this tool.

An Overview of the Creative Process Based on the Issued Actions

Within our framework, the dialogs created through exchanged messages and graphic construction of the networks of concepts are not only the probe of creative processes, as Lumsden argues in (Lumsden, 1999), but also a co-creative process achieved by two individuals. There are different definitions that address what creativity is, but generally it is related to the creation of something new and appropriate (Sternberg & Lubart, 1999; Runco, 2007). By asking to students reinforcing or acquiring a topic and represent it by means of Network of Concepts allows them producing an original and creative representtation according to their own understanding. Along with representations, we found that there are not similar network to each other, which is favorable to the concept of divergent thinking (Scott & Lyle, 2004) and development of cognitive skills for each individual. Thus, the creative process is involved in both the interaction between pairs to build the NoC and in the process of the development of skills. For the latter case, this work considers the following aspects to be dealt with concerning the creative process: the statement of an idea to be concretized or a problem to be solved; the search for relevant pieces to be assembled through an appropriate analysis; the creation of basic structures, which could be composed of at least two relevant pieces, by making an important exercise of analysis and synthesis; the assembly of the whole NoC, which implies again an important exercise of analysis, synthesis and construction of structures, as we previously stated.

Method for Analyzing the Process

We chose as a descriptive example the data of an Engineering course with 26 students, where 19% were women and the 81% were men, and which were instructed to reinforce the topic of "Agile Manufacturing". Such students were physically distributed to avoiding face-to-face communication during a session of two hours long approximately.

Along the time session, dialogs and Network of Concepts were recorded by our computational tool as they constituent elements were issued with a time mark of milliseconds. In this analyze we use the actions issued to create the network and dismiss the text messages for allowing readability in data.

Therefore, to analyze in general the construction process of the network we start by plotting the sequence of such constituent actions occurred in the shared space as shown by **Figure 5**. With this view we aim at visualizing how the process of construction took place. As a result we observe that actions occur in well-defined periods of time where both participants actively co-construct the network. In the same figure we can observe that actions are not continuously issued over time, but in compact intervals. This means that there are gaps between groups of issued actions which denote the process of exchanging messages where students get involved in discussion, negotiation and agreement.

To particularize the process, we chose some dyads with few actions that let us analyze and explain their co-creation process, also plotting few data enable their full visualization within this article. Thus, **Figures 6** and **7** show the contributions that each participant made to their respective networks. First, **Figure 6**

Figure 4.
Peers developing collaborative learning by building networks of concepts, the pairs are not at the same geographic place, thus avoiding a face-to-face collaborative situation.

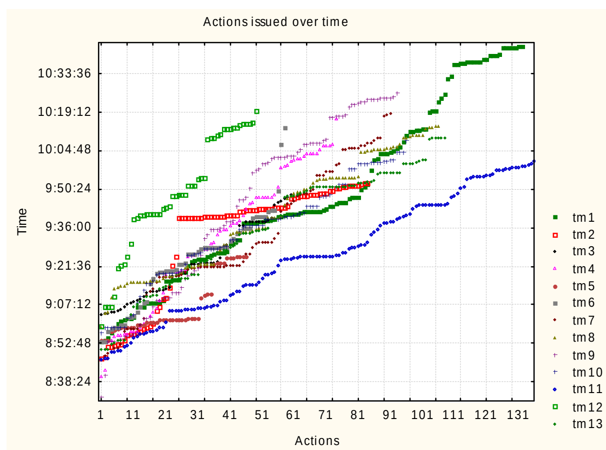


Figure 5.
Actions issued by thirteen dyads along a session of two hours.

shows that participant B6, who is a member corresponding to dyad 6, makes three groups of compacts actions, and participant A6 makes three groups also, the rest of actions seems to work as glue between those groups of actions. We mean by group of actions the sequence of actions issued over the time. For example, in **Figure 6** at the beginning of the plot there are four consecutive actions issued by B6, later, there are two actions issued by A6 followed by one more action of B6, these intercalated actions from both participants are what we consider as glue between groups.

On the other hand, even though **Figure 7** shows bigger discontinuities than the previous figure and there is more participation of member A2, who is a member corresponding to dyad 2, participant B2 seems to be an occasional contributor to the network construction.

In **Table 1** we present a summary of actions issued by all dyads and their subjects as well as the percentage of contribution of each member with respect to their partner. As a result, we can observe that in almost all dyads there were contributions of both members, with the exception of dyad four, where it is

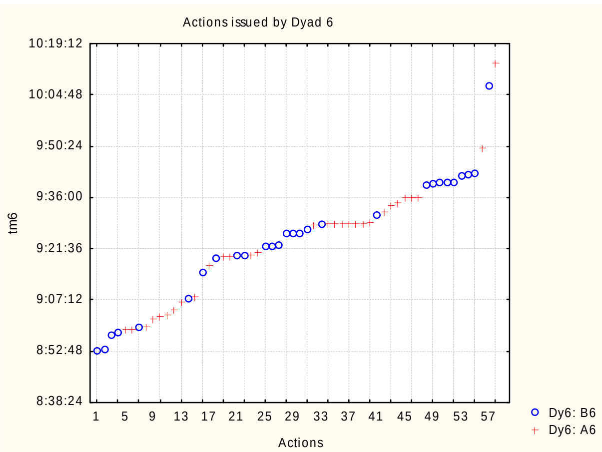


Figure 6.
Actions issued by dyad 6. In this figure we observe how the intercalated participation of both students B6 and A6 contributes along the process to co-creatively build the network of concepts.

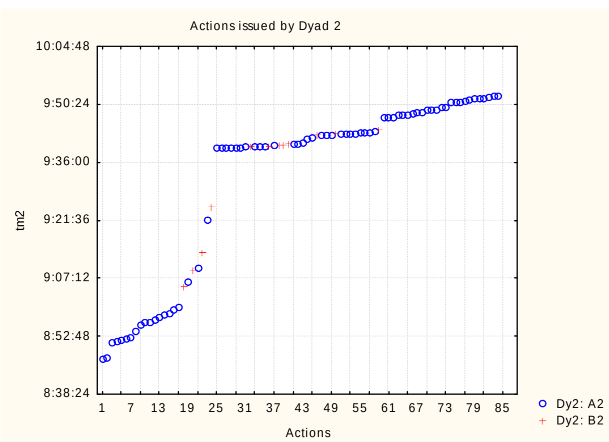


Figure 7.
Actions issued by dyad 2. In this figure we observe sequence of actions mainly issued by student A2, while student B2 participates sporadically.

Table 1.
Frequency table for total actions issued by students in dyads.

Category	Frequency Table		
	Count	Cumulative Count	Percent
A1	52	52	39.39
B1	80	132	60.61
A2	72	72	85.71
B2	12	84	14.29
A3	32	32	53.33
B3	28	60	46.67
A4	67	67	90.54
B4	7	74	9.46
A5	8	8	17.39
B5	38	46	82.61
A6	28	28	48.28
B6	30	58	51.72
A7	54	54	59.34
B7	37	91	40.66
A8	53	53	50.00
B8	53	106	50.00
A9	39	39	41.94
B9	54	93	58.06
A10	70	70	72.92
B10	26	96	27.08
A11	134	134	70.90
B11	55	189	29.10
A12	20	20	40.82
B12	29	49	59.18
A13	59	59	54.63
B13	49	108	45.37

clear that the network is the major result of one participant. In addition, there is the contrasting participation of dyad eight, where both members contribute uniformly in the co-construction.

At the end of this article, in appendix I, we present the final Network of Concepts corresponding to both dyads exposed herein in according to how they understood the topic been reinforced (Agile Manufacturing); for dyad 6 see **Figure 8**, and for dyad 2 see **Figure 9**). For each graphical representation, we can observe that each one is very different, but they share fundamental concepts like those cited in (Sanchez & Nagi, 2001) with respect to Agile Manufacturing, example of these concepts are adaptability, human factors, competitivity, cooperation, customers, e-commerce, technology, and information systems. Particularly in the case of dyad 2 (**Figure 9**), the shape of the network attracts our attention because we found that it could be influenced by a similar scheme from the reading of the article of Gunasekaran (Gunasekaran, 1998), therefore we dismiss the idea that the shape of the network were totally new in contrast to others. But we still consider the process as something new because of the coordination process to build the network.

Final Considerations

In this article, we exposed how a CSCL framework has pursued fostering a co-creative process for building Networks of Concepts and how the activities within it develop cognitive skills. Since 2008, we have applied the framework in under-

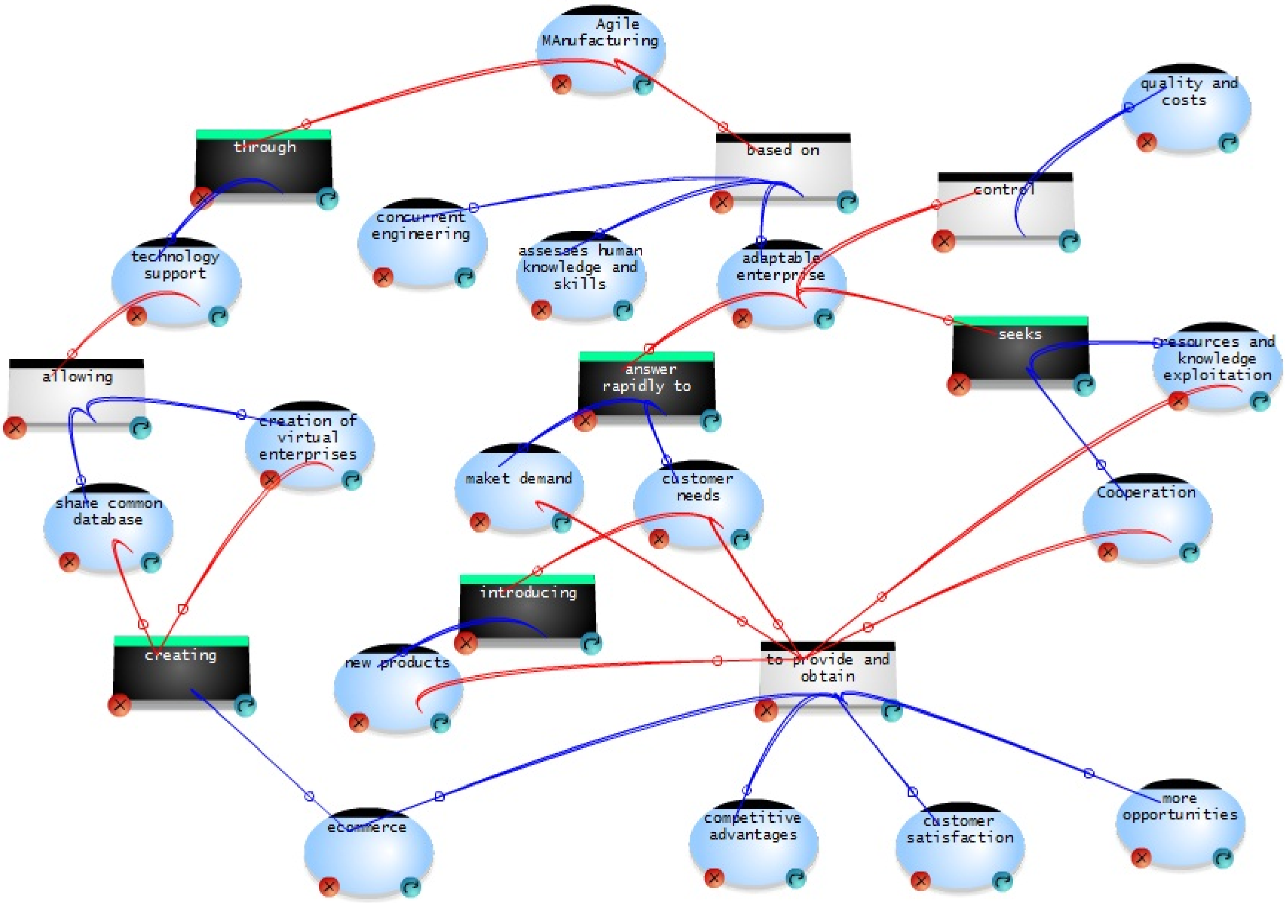


Figure 8.
The full network of concepts created by dyad 6 representing the topic of "Agile Manufacturing" with several appropriated concepts as well as a compact network, which can be considered as synonymous of a good synthesis. The network is transcripted as created by students.

graduate programs of Engineering and Computer Science. Later in 2010, we extended the framework to include the assessment stage and we decided to use this framework within different disciplines to promote their benefits. As a result, we started to work in other undergraduate programs such as Sociology, Accounting, Business Administration, and Molecular Biology. Herein, we presented just one particular case for Engineering, but we found it very remarkable that, in despite of working with such different disciplines and different sized groups, the development of the framework has not been an obstacle, and that the experience of all the participants (students/teachers) has been in general positive. During this time, we found that students enjoy working collaboratively and teachers observed a better assimilation of topics reinforced by the use of the framework.

Conclusion

On the one hand, we exposed how a co-creative process can be evidenced by plotting the recorded actions from the construction of Network of Concepts by using the "*issued action*" dimension, and not only by exploring the final outcome that is presented as original graphical constructions of Network of Concepts following hierarchical, centralized, arboreal shapes. Therefore, as a result we found that group of structures are created in very well defined amounts of time by both participants, looking at the quantities we found that students contribute with different effort and in some cases just one peer takes all responsibility (e.g. dyad 4 in **Table 1**) and just in rare cases actions are fully balanced (e.g. dyad 8 in **Table 1**). On the other hand, we have reinforced the idea that the co-creative process influence on the development of some relevant skills needed for the lifelong learning and problem solving, as mentioned before. As a creative goal, a challenge for students is to achieve a Network of Concepts as much semantic expressiveness as possible by obtaining a topology easily interpretable by third persons, such as other students and teachers. We mean by a semantic expressiveness NoC, a network that expresses correctly the linked concepts and is easily understandable as whole. As we have seen, the NoC is an abstract and synthetic representation of a knowledge, whose whole structure is composed of basic structures semantically correct, which in turn are composed of underlying pieces of knowledge (concepts). Thereby, the process to achieve the NoC entails the development of skills such as analysis, synthesis, abstraction, argumentation and construction. Finally, one of the potential applications of this research is the capability to evaluate a whole process with objective parameters as those shown here with independence of the knowledge domain, and the possibility to track structuration process at the syntactic level given by the groups and time frame identified in order to mediate the collaboration opportunely. Furtuer

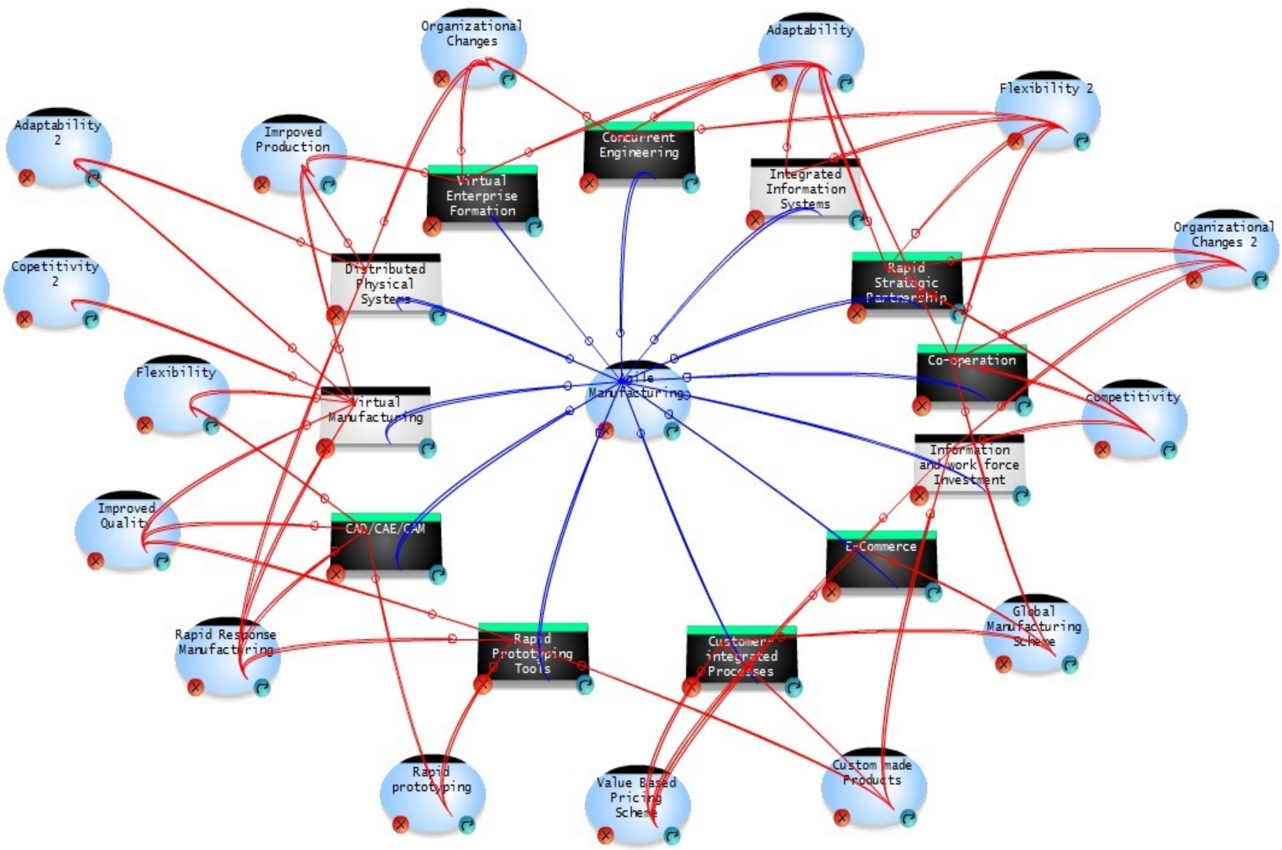


Figure 9.
The full network of concepts created by dyad 2 representing a very peculiar shape as a web. Structurally speaking the main difference is that all concepts are related in the central point as in a spider-web in contrast to more common hierarchical models herein evaluated. The network is transcripted as created by students.

analysis will be required to establish the adequate syntactic threshold in such early intervention process.

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