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A REFERENCE CURRICULUM FOR EDUCATION IN COLLABORATIVE NETWORKS

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A proposal for a reference curriculum for teaching Collaborative Networks at university level is introduced. This curriculum is based on the experience of the authors in teaching and disseminating corresponding concepts in the context of several international projects as well as on the findings of a survey conducted worldwide. A set of teaching units and the corresponding content are introduced. Guidelines for the application of the curriculum are given. A set of experiments and projects are also suggested as a support for the accompanying hands-on lab work. Finally, one concrete experience of application of the proposed curriculum is described.

1. INTRODUCTION

Education plays a vital role in facilitating the dissemination and broad acceptance of virtual organizations (VO) and other forms of collaborative networks (CNs). The practical development and exploitation of new collaborative network forms such as virtual organizations / virtual enterprises, VO breeding environments, professional virtual communities (PVC), virtual laboratories, virtual institutes, etc., is hindered by the lack of an organized and widely accessible body of knowledge on the related supporting concepts, models, technologies, processes, and methodologies. Although considerable progress has been achieved in recent years, most of the underlying knowledge in this area is possessed only by a limited number of researchers and engineers. In fact, the study of collaborative networks is still absent from most of the traditional university programs (Camarinha-Matos, Cardoso, 2004).

Nevertheless the situation is changing. As reported in previous works (Camarinha-Matos, Cardoso, 2004), (Garita, 2004), (Gloor et al., 2006), (Klen et al., 2005) several universities worldwide already offer courses on related topics and this number is increasing rapidly. As shown by a survey conducted in the scope of the ECOLEAD project most of these courses are however somewhat unbalanced, giving only partial views and, in many cases, biased by the scope of the department offering the course.

As the area is growing as an autonomous discipline, i.e. gaining its own "identity" (Camarinha-Matos, Afsarmanesh, 2005), it is becoming clear that there is a need to elaborate more comprehensive, less biased, programs. Similarly to what has happened with other disciplines in the past, it is necessary to establish a "reference curriculum" in order to:

- help extending the focus / coverage of early initiatives;
- help launching new training initiatives.

The main contribution of this chapter is a proposal for such a reference curriculum for a university-level course on collaborative networks. A preliminary version of the curriculum was first applied and evaluated in a number of cases (e.g. at New University of Lisbon, 1st ECOLEAD Summer School, Polytechnic University of Valencia, BEST Summer School in Lisbon) and also discussed in conferences and in the context of the IFIP Working Group 5.5 on Virtual Enterprises and e-Business and SOCOLNET – Society of Collaborative Networks (Camarinha-Matos, 2006), (Klen et al., 2005).

The version included in this article integrates the received feedback and acquired experience with the previous draft and represents a more consolidated proposal. Nevertheless, like with any other emerging discipline, this curriculum certainly needs to be periodically updated and improved. In addition to the curriculum itself, a number of practical experiments and projects are suggested to support the hands-on lab work of the students. Finally, the experience of applying this curriculum at the New University of Lisbon is reported.

2. FORECASTING THE NEEDS

In order to identify the level of interest and opinions about the teaching of Collaborative Networks, as well as the already existing initiatives, from the perspective of educators, a survey involving some prestigious Institutes around the world was performed in the context of the ECOLEAD project (Camarinha-Matos et al., 2005).

From the beginning it was clear that conducting an extensive survey for an emerging area would be a very resource consuming task. On one hand, in order to cover a significant number of geographical regions, the number of universities and other educational institutes would grow dramatically. On the other hand, even when focusing on a limited number of institutions, there is a major difficulty regarding the identification of which departments and which academic staff to contact. Being CNs a multi-disciplinary area, it is natural that teaching initiatives emerge in different departments. In order to determine the universe of institutions to contact for this initial study the following steps were followed:

1. *Select a preliminary group of top universities*. As a starting basis the list of the top 500 universities according to the "**Academic Ranking of World Universities**", organized by the Institute of Higher Education, Shanghai Jiao Tong University, was considered. Taking into account the limited resources available to perform this survey it was not feasible to consider this full list. Therefore, only a subset (66) of the list was selected:
   - The top universities per geographical region (5 from each of the following continents: America, Europe, Asia, Oceania, and 4 for Africa), plus

- An additional group of 42 institutions selected randomly from the remainder of the list.

The decision regarding the size of the target group was solely based on the estimated effort required and the available resources.

2. *Select other universities from web search*. In addition to the institutions selected in the first step, some other universities were added to the list when it was possible to identify, by a simple search on the web, that they already offer teaching initiatives on CNOs.

3. *Include other universities from analysis of conference publications*. Complementarily to the web search, a few other universities were selected via a brief analysis of the proceedings of past PRO-VE conferences.

As a result of this selection process, a total of 82 institutions were considered as the target "population" for this survey.

The next step was the identification of potential participants from selected institutions, i.e. which professors at those institutions to contact. For the cases of courses found on the web or through publications in conference proceedings, the contact persons were directly identified. The other cases required and extensive and focused manual search through the web sites of the selected institutions (focusing mainly on engineering and management departments). As a result, a total of 1024 academic staff was contacted from the 82 institutions out of which (only) 76 replies were received. The received answers included contributions from 44 institutions (i.e. about 54 % of our target universe of institutions). Table 1 below summarizes the participation per country.

Table 1 – Respondents per country

Countries	USA	Germany	Australia	South Africa	Brazil	Finland	Hong-Kong	Mexico	Portugal	Sweden	UK	China	Costa Rica	Denmark	France	Italy	Netherlands	Norway	Singapore	Total
19	10	5	4	3	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	44

The following diagrams illustrate some of the results of this survey. More details can be obtained in (Camarinha-Matos et al., 2005).

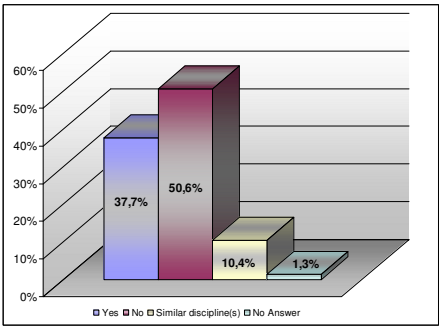

Figure 1 - Is there a dedicated discipline on CNs in your Institution?

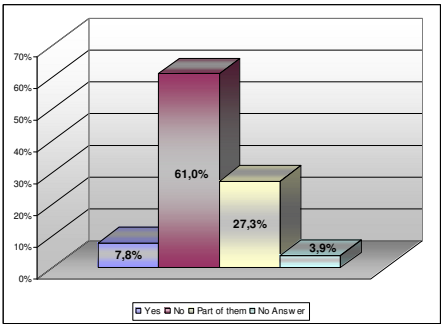

Figure 2 - Do you consider the concepts in the CNs area already consolidated?

These percentages need to be read with some caution. They do not represent a percentage of the full universe of high education institutions but rather a percentage of the respondents to the survey, i.e. people that are involved in the area or likely to be motivated for its importance. Nevertheless, under this constraint, these numbers give an indication that several CNs teaching initiatives already exist.

The answers to this question clearly confirm the need to invest more on the consolidation and structuring of knowledge in the area.

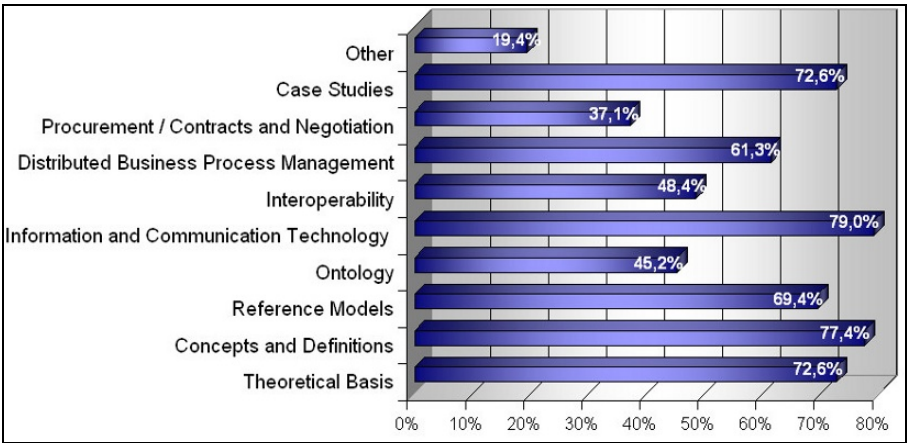

Figure 3 - Which subjects should be included in a CN basic course?

Fig. 3 summarizes the list of topics suggested by the respondents to include in a basic course. This diagram is certainly affected by the options offered in the questionnaire but nevertheless it gives some useful indications:

- ICT is certainly associated with the core issues in CNs.
- Case studies are very important to create motivation, illustrate the applicability of the concepts, and help identifying requirements.
- The theoretical foundation (including theoretical basis, concepts and definitions, reference models, and ontologies) is fundamental in a training program.
- Interoperability, although somehow important, is not perceived as too critical. The same with procurement, contracts and negotiation.

Based on the results of this survey and additional search on the web, the second phase of this study was devoted to identify and collect information about existing teaching initiatives. The existence of quite distinct initiatives made it clear that it would not be reasonable to compare them all together. Therefore, three main kinds of courses were identified:

- Formal university courses fully dedicated to the subject. This case typically includes a one-semester course that is offered as part of a formal university program.
- Short courses dedicated to the subject or long courses that include a short module on CNs.
  In this category, either the course is not fully dedicated to the "Virtual Enterprise" or "Virtual Organization" paradigms or it is a short course or

summer course.
- On-line / Web-based courses.

Among these categories, the most significant kind of courses to analyze for the purposes of this work is the first one – the University initiatives fully focused on CNs and related manifestations.

Most of the identified initiatives (88%) are offered either at the undergraduate or Master level. It is also important to notice that there is quite a large heterogeneity in terms of the structure of the university courses. Some universities consider a model of 3 years (bachelor) plus 2 years (master), while others offer a 2-year master degree after a 5-year university course. The two notions (and levels) of master are necessarily different. In other countries there is a single degree for engineering courses (5 or 5.5 years). PhD courses, due to their specificity, are to a large extent out of the scope of this study. In many universities the PhD program does not include a formal training program but rather research work only. The ongoing implementation of the Bologna model in Europe is likely to lead to a more uniform structure.

Table 2 shows the main initiatives identified for formal university courses. This is certainly not a full survey, but it nevertheless offers a good set of base information.

Table 2 – Examples of formal university courses

#	Course name	Location / Institute	Duration
1	Virtual Enterprises	New University of Lisbon Portugal	1 semester
2	Virtual Organizations	ITCR Costa Rica	1 semester
3	Enterprise Integration Systems	UFSC Brazil	1 semester
4	Information Systems / Virtual Organization	City University of New York USA	1 semester
5	Agile Virtual Enterprise	Universität der Bundeswehr München	1 semester
6	Management and Information Systems	University of York UK	1 semester
7	Seminar in Virtual Collaboration	University of Nebraska at Omaha USA	1 semester
8	Organizational Networks and Communication	Helsinky University of Technology	1 semester
9	Managing in a Virtual Environment	Claremont Graduate University	1 semester
10	Virtual Organisation Management	The University of Queensland	1 semester
11	Information Systems	Edith Cowan University	1 year
12	Information Based Manufacturing	New Mexico State University	1 semester
13	Coordination and Control in the Virtual Organization.	The FOX School of Business and Management	1 semester
14	Virtual Organisations	City University of Hong-Kong	1 semester
15	e-Business Technologies	University of Porto	1 semester

In terms of focus of each course, the first indicator is the course's name. Here, many differences can be noticed. While some courses take a general / horizontal point of view, some others choose one particular perspective about these new paradigms, like the enterprise integration or the agility characteristic. On the other hand, two other main perspectives can be identified in the course names analysis: management and organization.

Based on the information collected during this survey and some additional web search, a number of example curricula were collected. This collection includes curricula from both formal university courses and also from some of the short courses / modules. These materials, together with the experience acquired in several training actions conducted by various R&D projects in which the authors were involved, were the basis for the preparation of the current curriculum proposal.

3. OBJECTIVES OF THE CURRICULUM

The following generic and specific objectives are considered in this proposal:

Generic objectives. A reference course on CNs shall:

- Provide an intuitive introduction to the paradigm of CNs, with illustrations based on case studies, and discuss why collaboration is becoming a key competence for organizations and professionals.
- Provide a good understanding of the various technical and scientific components involved in CNs.
- Develop systems integration competencies (holistic perspective).
- Contribute to help the student develop planning and problem solving capabilities in the context of integrated and distributed collaborative systems.
- Develop the capacity to attack problems whose specification is incomplete, leading to focus on creativity and search for new systems and solutions.
- Clarify and exemplify the multi-disciplinarity of the CNs paradigm.
- Develop an understanding and a critical perspective regarding the impacts of ICT in modern society.

Specific objectives. As specific objectives the course shall help the student understand the various underlying topics in CNs and the way they are inter-related, which include:

- (Business) process modeling skills and familiarization with related tools, such as workflow tools.
- The basic functionalities of an interoperable infrastructure for collaborative networks.
- A capability to plan a CNs infrastructure fitted to target scenarios.
- The issues of integration / interoperability among different technologies.
- Skills to specify coordination mechanisms.
- The role and limitations of standards in supporting collaboration.
- The basic focus of the most typical manifestations of collaborative networks.
- The main strategies and mechanisms for safe communications and distributed information and knowledge management.
- The socio-economic impacts of the introduction of new technologies and new paradigms in the companies.

- A general perspective of the trends and expectations in CNs.

Clearly many of these objectives are not achievable if only presented through the theoretical material suggested in the curriculum. Their achievement also depends on many other factors such as the practical work (lab experiments), the support materials and case studies, and even the pedagogic approach. As the survey work also showed, there is a lack of support materials for teaching CNs. At least in terms of materials available through the web, only a few support texts and slides could be found (in several cases, in languages other than English). In our study, direct enquiries to the persons that have organized courses, also did not produce more information either. One of the major difficulties observed so far is the lack of well prepared examples / case studies and laboratory experiments that could provide some practical experience and, at the same time, fit within the time limits of a single course.

From the didactic and course *delivery* perspectives it would be interesting to exploit new approaches based on collaborative networks and e-learning. However this will require considerable resources to develop. A preliminary study regarding pedagogic approaches for training and education through distance learning, although limited to the extended enterprise, is done by the GEM project (Haugen et al., 2002).

4. SYLLABUS

4.1 Units

In order to cope with the mentioned requirements and objectives, the following main units are proposed for a reference curriculum on Collaborative Networks:

UNIT 1: **MOTIVATION FOR THE PARADIGM**

This first unit aims at creating a motivation for the course through a brief presentation of application areas, illustrated by concrete examples in industry, services, government, etc. A brief historic overview of the industrial organizational paradigms leading to collaborative networks as well as a summary of current technological and organizational trends is presented. For each example an attempt to identify the main involved problems (e.g. organizational forms, processes, cooperation, and collaboration forms) is made, calling the attention for the potential contributions from other disciplines. The socio-economic importance of each case is also briefly highlighted.

UNIT 2: **BASE CONCEPTS OF COLLABORATIVE NETWORKS**

After the motivation phase, the base concepts are introduced. Considering the large variety of collaborative networks, a categorization of the various forms is made and a taxonomy is introduced in order to give students a global perspective of the area. The main types of collaborative networks, namely the long term strategic alliance as well as the dynamic (short term) opportunity driven collaborative network is addressed. The various actors involved in a collaborative network as well as the roles they can play are identified. Finally the life cycle of a collaborative network is discussed in terms of its main phases.

UNIT 3: **VO BREEDING ENVIRONMENTS**

The concept of Virtual organization Breeding Environment (VBE) is elaborated and justified. Illustrating examples are provided. The components, structure and life cycle of this organizational form as well as its involved actors and roles are identified and characterized. Main processes, working & sharing and governance principles are discussed. The architecture and supporting functionalities for a VBE management system as well as the corresponding information and knowledge bases are introduced in a step by step approach. The issues of management of competencies, VBE assets, and trust, as well as the value systems are analyzed in terms of modeling, support functionality, and practical use.

UNIT 4: **VIRTUAL ORGANIZATIONS**

The concept of Virtual Organization (VO) previously introduced is briefly revisited and the conditions for its emergence are discussed. Particular emphasis is devoted to the creation of dynamic VOs in a VBE context. The life cycle – creation, operation, evolution, and dissolution – of the VO is analyzed and the supporting information / knowledge and functionalities are discussed together with the involved actors and roles. Special attention is devoted to the consortia formation, negotiation, distributed business process planning and supervision, performance management, dissolution and inheritance, and business modeling. The relationship to other more classic networks such as supply chains is made. Examples in various domains are analyzed.

UNIT 5: **VIRTUAL COMMUNITIES**

The concept of Virtual Community (VC) previously introduced is briefly revisited and compared with the concept of VO. A typology of VC is suggested and a particular attention is devoted to Professional Virtual Communities. The components, structure, and life cycle of PVCs are discussed and modeling options introduced in comparison with the VBE. Architectural options for a PVC management system and supporting functionalities are analyzed. The creation of Virtual Teams within a PVC and their management are studied. Governance principles, main processes, intellectual property issues, and social computing issues are discussed.

UNIT 6: **BASE INFRASTRUCTURES**

The establishment of adequate communication channels and protocols is a basic pre-requisite for the operation of collaborative networks and interoperation among its components and subsystems. Therefore the main logical components of a communications infrastructure are introduced. Various implementation approaches are discussed, including agent-based and service-oriented approaches. The security issues deserve special attention and the various mechanisms and technologies are discussed in terms of their benefits and limitations. Emerging computing models, mobile and pervasive computing are briefly studied in terms of their contribution to collaborative networks.

UNIT 7: **INFORMATION MANAGEMENT**

Information management in a distributed, multi-ownership context is discussed and mechanisms for information sharing, information exchange, and access rights definition and enforcement are introduced. The role of standards is discussed and main standards briefly characterized. Various information management approaches are also discussed, with particular emphasis on the federated information management systems. Different implementation approaches are also discussed.

UNIT 8: **SPECIAL INFORMATION EXCHANGE STANDARDS**

A number of standards particularly relevant for collaborative networks are introduced and analyzed. Among them: EDI (Electronic Data Interchange), which in historical terms represents one of the first tools for cooperation among enterprises, is introduced and briefly characterized. The interaction between EDI and ERP systems is discussed. The EDIFACT standard is presented and current XML-based implementations mentioned. The STEP standard for the exchange of technical product data is described and its applicability in virtual enterprises is discussed. Support technologies as well as PDM systems are identified. Other emerging standards for information and knowledge exchange are pointed out.

UNIT 9: **COORDINATION MECHANISMS**

Various modalities of collaboration are discussed and the corresponding coordination needs introduced. The concept of coordination is highlighted. Process-based coordination and the corresponding distributed business process modeling, planning, scheduling, and execution are particularly focused. Languages for business process modeling are introduced. Workflow / process execution engines are discussed and standard architectures for inter-organization workflow are analyzed. Finally challenges in flexible coordination are raised and the students are motivated to suggest approaches.

UNIT 10: **MANAGEMENT OF COMMON ONTOLOGIES**

Considering the complexity of the collaborative network environments, a number of benefits are gained through provision of the ontology for these networks. Development of common ontology for collaborative networks enhances: i) common understanding of their related entities and concepts, ii) classification of their knowledge in order to facilitate the knowledge interoperability both among the network participants and among different networks, as well as iii) the development of a management system for collaborative networks and the needed databases and data/knowledge access functionality. Approaches for a common ontology are presented and mechanisms required for ontology customization and management are addressed.

UNIT 11: **e-COMMERCE AND e-MARKETS**

Although these issues are not part of the Collaborative Networks, they share a number of common issues. Therefore the concepts of e-Commerce and e-Market are introduced and the differences and commonalities in relation to collaborative networks highlighted. The involved organizational issues are discussed and

supporting architectures and technologies introduced. Finally the contact points between these areas and collaborative networks in a new digital ecosystems context are discussed.

UNIT 12: **NON-TECHNOLOGICAL ISSUES**

The success and effectiveness of implementation of the collaborative networks depend on a number of other important issues besides the technological solutions. In this unit social, ethical, legal, and organizational issues are addressed and current trends pointed out. New business models and their applicability are discussed, namely through the introduction of examples. Marketing and sustainability of the network, intellectual property management, systems of incentives, etc. are other relevant issues.
Alternatively each of these topics can be introduced in parallel and along the other units.

UNIT 13: **REFERENCE MODELS**

The concept of reference model and its need is introduced. Modeling frameworks are presented and discussed. Example reference models are introduced and methods for models evolution and derivation of particular models are briefly discussed. A reference modeling framework for CNs will be presented, addressing its specific dimensions and elements. Some CN reference models, for example for VBEs and VOs are presented.

UNIT 14: **EMERGING COLLABORATIVE FORMS**

In this last unit, and after a brief summary of the various collaborative forms studied in previous units, a discussion of possible new models and generalizations is made. As a starting basis, new forms of collaborative e-government, e-science, virtual institutes, Virtual laboratories, etc, are discussed. Other generalizations include: networks of sensors, networks of machines, etc. Afterwards students are encouraged to suggest other application areas and identify the innovative collaborative forms needed.

4.2 Curriculum

Based on the above units, Table 3 shows the proposed reference curriculum.

Table 3 – Reference curriculum for Collaborative Networks

UNIT	TOPICS
1. MOTIVATION FOR THE PARADIGM	▪ Practical examples of collaborative networks. ▪ Historic overview. ▪ Technological and organizational trends. ▪ Discussion of the usefulness / benefits and current limitations of CNs
2. BASIC CONCEPTS OF COLLABORATIVE NETWORKS	▪ Categories of CNs. ▪ Actors and roles. ▪ Life cycle and related key processes.
3. VO BREEDING ENVIRONMENT	▪ Concept and examples. ▪ Components, structure, actors and roles. ▪ Competencies and assets.

	▪ Processes and governance principles. ▪ VBE management system. ▪ Trust and value systems.
4. VIRTUAL ORGANIZATIONS	▪ Concepts, organizational models and operational rules. ▪ Life cycle. ▪ VO creation process and functionalities. ▪ VO management functionalities and performance measurement. ▪ VO dissolution and inheritance.
5. VIRTUAL COMMUNITIES.	▪ Concepts and typology. ▪ Components, structure, and life cycle. ▪ Professional virtual communities (PVC). ▪ PVC management system. ▪ Virtual teams. ▪ Governance principles and social computing.
6. BASE INFRASTRUCTURES.	▪ Computer networks basics. Base Internet technologies. ▪ Components of a communication infrastructure. ▪ Implementation approaches: agent-based, service-oriented, etc. ▪ Security mechanisms and technologies. ▪ Emerging computing models.
7. INFORMATION MANAGEMENT	▪ Information management requirements. ▪ Mechanisms for information sharing and exchange. ▪ Access rights definition and enforcement. ▪ Federated /distributed information management.
8. SPECIAL INFORMATION EXCHANGE STANDARDS	▪ Importance of standards in collaborative networks. ▪ EDI and EDIFACT. ▪ Interaction with legacy systems. ▪ XML and its role. ▪ STEP and PDM. ▪ Other standards.
9. COORDINATION MECHANISMS	▪ Collaboration modalities. ▪ Concept of coordination. ▪ Distributed-business process modeling and planning. ▪ Distributed scheduling and re-scheduling. ▪ Languages for business process modeling. ▪ Workflow and process execution engines. ▪ Challenges in flexible coordination.
10. MANAGEMENT OF COMMON ONTOLOGIES	▪ Glossary and specification of base entities and concepts. ▪ Core level common ontology for collaborative networks. ▪ Ontology engineering approaches. ▪ Learning ontology from unstructured sources. ▪ Semi-automatic customization of common ontology to specific domain/application
11. e-COMMERCE AND e-MARKETS	▪ Concepts of e-Commerce and e-Market. ▪ Relationships to collaborative networks. ▪ Support institutions. ▪ Support systems. Portals. Negotiation. ▪ CRM. Logistics.
12. NON-TECHNOLOGICAL	▪ Social, ethical, legal, and organizational issues. ▪ Contractual issues.

ISSUES.	▪ New business models. ▪ Collaboration sustainability mechanisms. ▪ Intellectual property management.
13. REFERENCE MODELS	▪ Concept of reference model. ▪ Modeling frameworks. ▪ Examples of reference models. ▪ Derivation and evolution methods.
14. EMERGING COLLABORATIVE FORMS	▪ Summary of studied collaborative forms. ▪ New application examples: collaborative e-government, e-Science, Virtual Institutes, Virtual Labs, etc. ▪ Networks of machines, networks of sensors. ▪ Other emerging cases.

4.3 Sequence of topics

The proposed curriculum does not imply a rigid sequence of topics although some dependencies among subjects can naturally be identified, as shown in Fig. 4. The "Non-technological issues" can either be introduced towards the end, or they can be "merged" with the other topics and be addressed when the VO Breeding Environment (Afsarmanesh, Camarinha-Matos, 2005), the Virtual Organization / Virtual Enterprise (Goranson, 1999), and the Virtual Communities are introduced. Another approach is to emphasize technological aspects in the first phase, giving students the background to start the laboratory work, and postpone the other issues to a later stage.

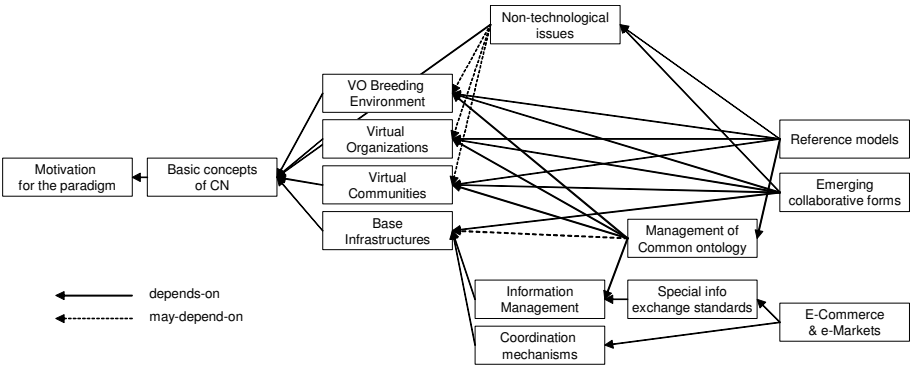

Figure 4 - Main dependencies among subjects

Taking the indicated dependencies into account, various alternative schedule sequences can be considered. Two examples are illustrated in Fig. 5.

Option A corresponds to introduce the main concepts and organizational forms before the technological aspects. This option can be adequate if the experimental lab work does not start in parallel with the theoretical lectures.

Option B might be more adequate for those cases in which theory and practical work have a parallel schedule. For instance when the course plan includes a

theoretical lecture and a practical lecture every week, as it is common in some universities. This option might be more motivating for students that want to have "hands-on" experience from the beginning.

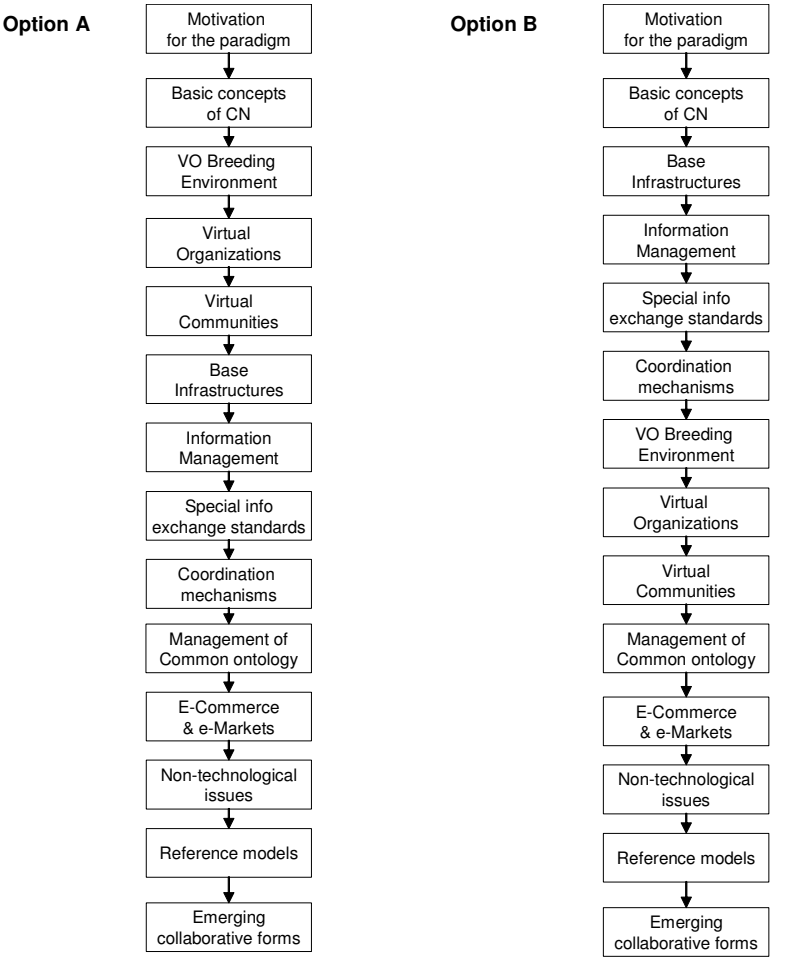

Figure 5 - Examples of sequences of topics

5. LAB WORK

Experimental work aimed at giving students some practical experience can be organized as projects. Instead of small disconnected experiments to be performed by students, the basic idea of a "project" is to have more ambitious lab works in which various groups of students design and develop components to be integrated in a collaborative platform. In this way, the working method to be adopted by the students will be collaborative, giving them more real understanding of the issues

involved in a collaborative network. These projects are supposed to be developed along several sessions, typically along one semester.

Examples for students with a background in ICT

Example 1: *Infrastructure to support a central Certification Breeding Environment*

Scenario. Consider you want to build one house from scratch. You start buying the land and contacting an architect to elaborate a project design for your house. After the project is elaborated and you got the necessary licenses, the house construction starts and things go on normally but, as it seams to be usual, instead of the planned 12 months you realize that the key came to your hands only two years after the construction started.
The main reason for the delay was the need of getting several certifications along the construction process, namely:

- Construction certification – got in the City Hall, needed for the construction to start, …
- Electrical Certification – needed to guarantee the electrical installation, …
- Communications Infrastructure Certification – needed to guarantee the quality of the communication infrastructure, …
- Usage Ability Certification – final certification needed for you to be able to live in the new house.

Sad with all the time lost, you decide to propose to your city council the creation of a Centralized Website where people could apply for any kind of certification services.

Objectives. This work aims at designing and developing a platform to support public certification processes for buildings, i.e. the support of a Certification Breeding Environment (CBE). Based on this framework, a Certification Virtual Organization could be created for each needed specific certification process. Taking into account the distinct phases of the software lifecycle this lab project will be divided into 4 phases: Analysis, Design, Development and Tests. For the analysis phase, the students should identify the system goals and skeleton, i.e., who are the actors, which modules will compose the system, what are their functionalities or features – the Use Cases. In this specific context, a discussion has to take place in order to clearly identify the goals of the infrastructure to be developed – the Certification Breeding Environment, namely:

- Register Certification entities, as well as their capacities / certification fields that the entities are able to certify.
- Find, within the CBE, entities that are able to provide specific certifications.
- Create a Certification Business Process – CBP, composed of a graph of certification Services associated to specific certification entities from the CBE.
- Execute and Monitor the execution of specific CBPs.
- …

In terms of the CBE platform, it must contain modules responsible for:

- Storage and management of the service provision members.

- Provide an interface to the certifying entities.
- Provide an interface for clients who need to access certification services.
- Provide an interface for the creation of Certification Value Added Services, through the creation of workflow specification of CBPs.
- …

Working Method. Students will be divided in groups to discuss the needs and constraints for this infrastructure. Each group makes a presentation of their work in the third lab session and proposes a final System Architecture, as well as the development technology to use. After all the proposals are discussed, the class will decide a common final System Architecture and the development technology to use. Each group of students will then be given a specific set of modules from the architecture to design, develop, integrate and test. In other words, each group will contribute with a distinct piece of the global system. Nevertheless, all groups have to be aware of what is going on with the other groups – the difficulties they are facing, the results they are producing, etc., in order to facilitate the final integration and improve the overall performance.

Example 2: *Infrastructure to support a PVC of Engineering consultants*

Scenario. A group of engineers from different specialties and living in different geographical regions / countries are organized as a PVC to provide consulting services. The PVC interacts with potential customers through a web portal. Customers will see this community as a service market.
Basic services can be combined into higher level services (value added services) in order to better respond to market opportunities, implementing, in this way, a kind of "learning system". Therefore, it shall be possible to use the output of a service as input for another service.
The coordination of a value-added service execution is also supported by the platform that keeps track of the status of evolution, exceptions, etc.

Objectives. This work aims at designing and developing a platform to support a Professional Virtual Community devoted to offer engineering consulting services. The typical phases of Analysis, Design, and Development shall be carried out. For the analysis phase the students shall be organized around a forum, playing different roles, in order to identify and characterize:

- The needs from the end-users point of view.
- The possibilities offered by current ICT tools and systems.
- The opportunities for commercial exploitation.

The next phase shall involve the design of the system's architecture, with a clear identification and specification of the various needed modules, as well as their interactions.

During the implementation, each group of students (2 or 3) will develop a specific module and will be responsible for the integration of this module with the other modules.

Some initial questions to motivate the work:

- Which basic functionalities are needed to interact with potential customers?
- Which basic functionalities are needed to support the organization of a value-added service?

- Is it feasible to have shared information spaces? How to deal with information visibility and access rights?
- How to keep track of the execution status of services?
- How to model the support information structures?

Working method. Each group of students will be given a specific task in order to add value to the common goal, just like in a virtual community. In other words, each group will contribute with a distinct piece of the global system. Nevertheless, all groups have to be aware of what is going on with the other groups – the difficulties they are facing, the results they are producing, etc., in order to facilitate integration and improve the overall performance. During the initial analysis phase, students are supposed to also identify existing platforms and tools that will facilitate the development.

Example for students with other backgrounds

Example 3: *P2P Social Networking tools to support PVCs*

Scenario. Imagine the following situation: you, together with your classmates, are part of a Professional Community which basically consists of the students of the course. You are together in a Community because you have similar interests and goals as for instance to learn about Collaborative Networks, to develop your competencies and to work collaboratively. Now, imagine further: the relation among the members of this Community will mainly be mediated through the use of computers. There will be face-to-face interactions, but these will not be the predominant ones. The tools used for these interactions will be the ones used for P2P social networking: Skype, MSN, Orkut, blogs, videologs, emails, SMS, GoogleSpreadsheets, etc. Now the question is: can you work together and collaboratively according to this social and organizational structure taking advantage of the internet-enabled society?

Objectives. The students will form a Virtual Team to work collaboratively in order to put together a project proposal to be submitted (hypothetically) to a Funding Agency call. The expertise aggregation should allow the elaboration of a proposal in the field of Collaborative Networks. In this sense, students have to take into account the current topics and the Open Calls for project proposals. Guidelines and rules to elaborate the proposal are the ones provided by the funding agency.
Some initial questions to motivate the work:

- How can the work be distributed among the members of the Virtual Team?
- Which governance principles are going to be used / adopted?
- How can conflicts be handled?
- How can the quality of work be measured?
- How to deal with Intellectual Property Rights?
- How to deal with trust issues?
- How can the tasks be monitored with transparency?

Working method. Students will have two face-to-face meetings mediated by the course assistant namely: the first and the last lab sessions. In the first one, the experiment will be explained and the roles will be pre-defined according to the background and competencies of each participant. Also during the first session, a brainstorming on the project idea and the definition of start-up tools will take place.

In the last lab session, a round table will be organized to discuss and evaluate the procedure, the achievements as well as the strong and weak points of the experiment. All other lab sessions will be carried out remotely. Students will interact either from home, office or from the University premises. The remote lab sessions will be monitored by the course assistant. The first remote session will be used to agree on the set of tools to be used as well as on the topic to be developed for the project proposal. If other interesting tools are identified *a posteriori*, they might be suggested and included in the set if the participants agree on.

Ideally, students should try to discuss issues related to the experiment using only the identified tools (and not informal personal chats, for instance). With this lab project, students will be exercising and practicing concepts and models related to: working and sharing principles, governance, trust, management, IPR and transparency in a CN environment.

6. APPLICATION

Summer course. Part of the ideas suggested in this curriculum was tested in an ECOLEAD Summer School held in Helsinki in 2006.

Figure 6 – ECOELAD Summer School in Helsinki

Experience at UNL. An instantiation of the proposed curriculum has been included in the Electrical and Computer Engineering program of the Faculty of Sciences and Technology of the New University of Lisbon. This is an integrated MSc program (5 years) and the CN course is entitled "Virtual Enterprises". Although the course is, for historic reasons, entitled Virtual Enterprises, it covers all CN-related subjects proposed in this curriculum.

This course is located in the summer semester of the 4th year of the master program. Previous to this course, students have gone through several other courses that provide important ICT background to facilitate the understanding of the Virtual Enterprises curriculum. The following diagram illustrates these main subjects that constitute relevant background for the CN course (Fig. 7).

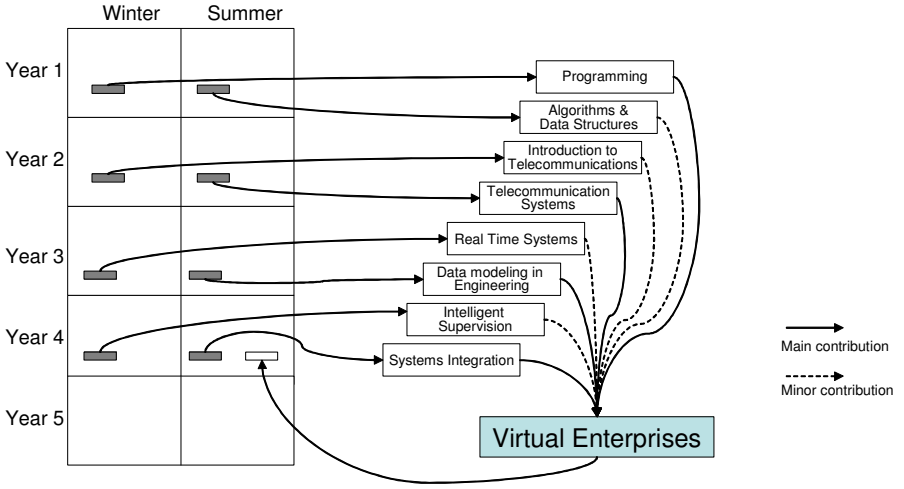

Figure 7 - Virtual Enterprises course and supporting courses

In the first occurrences of this course (till 2006), the course included 14 theoretical lectures of 2 h each, and 14 lab sessions of 3 h each. With the recent adaptation of the program to follow the Bologna model, the lab sessions were reduced to 2 h each. The course spans along 14 weeks; in each week there is one theoretical lecture and one lab session.

Given the nature of the program where this course is included, a strong emphasis on the ICT aspects was naturally adopted. The implementation of such a course with a strong laboratorial component faced a number of obstacles, namely:

- Complexity of the area;
- Lack of tradition of teaching these subjects;
- Lack of appropriate didactic materials;
- Dilemma between the option of increasing the number of students per lab session (limited by the available lab resources) or increasing the number of times each lab session is repeated (limited by the university policy regarding hiring new teaching assistants). But in spite of these obstacles, the adopted approach was to keep a strong laboratorial component in order to give students a sound hands-on experience.

Although this course is offered as elective (optional), the number of registered students has been growing every year, as shown in Fig. 8.

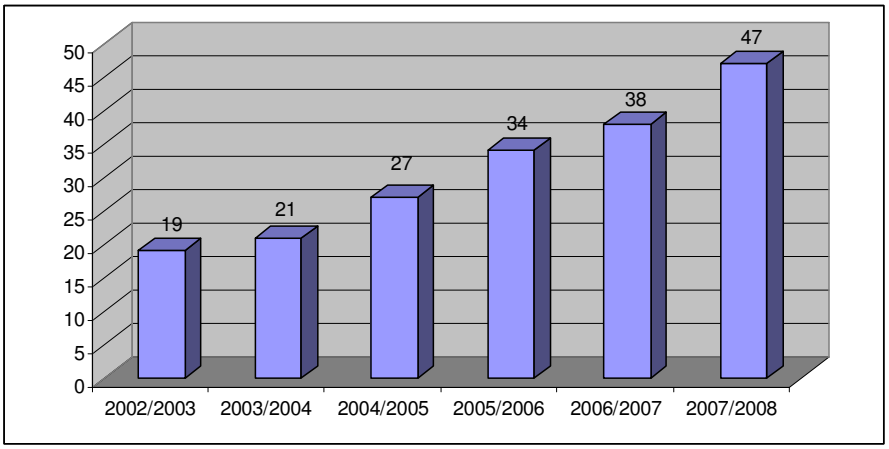

Figure 8 - Evolution of registered students for the Virtual Enterprises course

In the last 3 years, due to the number of students, the lab sessions had to be duplicated, with half of the students attending each turn. As lab work, a different project, based on the examples provided in section 5, has been successfully implemented every year. At the end of the semester it has been possible to demonstrate a working integrated system composed of modules developed by different groups of students.

As an indicator of success, in the year 2004, the project example nº 2 described in section 5 (students with ICT background) was adopted. The developed work was submitted to the Microsoft competition "**Imagine Cup**" and won the 1st position in the national competition, taking a group of students to the world finals in Brazil. The developed system was called "Collaborative Networked Environment – CNE" and the central aim of the infrastructure was to put together various consultants, as described before. Follows a brief description of CNE usage:

1. [**Consultant Registration**] - Other than personal data, each consultant provides a set of services he is able to offer to the virtual community. As more consultants register, the

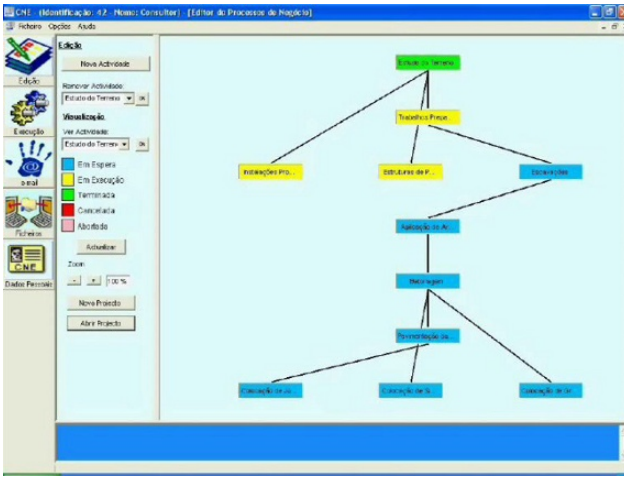

Figure 9 - CNE – Collaborative Networked Environment

resulting community gets bigger, as well as the provided services increase.

2. [**New Business Process Model Creation**] – Each member of CNE can start a new Business Process Model. The typical case is when such member finds a new Business Opportunity that he cannot fulfill alone. In that case, he comes to CNE to find the consultants that complement his services, in order to respond to that specific Business Opportunity.
3. [**Workflow Model Design**] - The consultant starts identifying the needed activities and the correct transitions. After that, he selects the services to be implemented in each activity from the CNE-services-pool.
4. [**Partners Selection**] – The next step is the selection of a specific consultant to execute each service. This task is supported by a performance supervisor included in the system, providing distinct ordering criteria for the consultants' set available for each service. Finally each selected consultant is contacted by the system, asking if he wants to join this Virtual Team that is about to be formed. The process repeats until all the services have an executor and the Business Model gets complete.
5. [**Business Process Workflow Model Execution**] - CNE includes a Workflow Engine responsible for this task, sending a message to each consultant when the time for his service to start comes. When each consultant finishes the specific service, he sends back a message to the engine, eventually including relevant files, and the process is repeated for the next consultant(s) on the workflow graph.
6. [**Execution Monitoring**] - CNE also provides an execution monitor, enabling all the consultants involved in a common Business Process to see the state of its execution (as shown in Fig. 9).

7. CONCLUSIONS

The proposed curriculum is aimed to provide a basis for a *reference*. Specific courses can be derived from this general reference curriculum, taking into account the specific context where the course will be introduced and the target students. Some guidelines are provided for this instantiation, namely in terms of where to put the emphasis and which sequence of topics to follow.

An instantiation example of the suggested syllabus was implemented at the New University of Lisbon and results of its application were briefly reported. This particular instantiation, together with other specific teaching actions (e.g. ECOLEAD Summer School, BEST Summer School, Module on Collaborative Networks introduced in the Master program on Logistics of the Polytechnic University of Valencia), show the feasibility of the proposed curriculum. Nevertheless, as Collaborative Networks is a new and very dynamic field, a training curriculum for this area certainly needs periodic revisions and improvements. Therefore, the current proposal has to be seen as an initial basis.

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8. REFERENCES

Afsarmanesh, H., Camarinha-Matos, L. M., 2005). A framework for management of virtual organization breeding environments. In Collaborative Networks and their Breeding Environments (L.M. Camarinha-Matos, H. Afsarmanesh, Ed.s), pp. 35-48, Springer, Boston.

Camarinha-Matos, L. M., 2006. Towards an education curriculum on Collaborative Networks, IFIP Newsletter, March 2006.

Camarinha-Matos, L. M.; Afsarmanesh, H., 2005. Collaborative networks: A new scientific discipline, *J. Intelligent Manufacturing*, vol. 16, Nº 4-5, pp439-452.

Camarinha-Matos, L. M.; Afsarmanesh, H., Ollus, M., 2005. ECOLEAD: A holistic approach to creation and management of dynamic virtual organizations. In Collaborative Networks and their Breeding Environments (L.M. Camarinha-Matos, H. Afsarmanesh, Ed.s), pp. 3-16, Springer, Boston.

Camarinha-Matos, L. M.; Cardoso, T., 2004. Education on Virtual Organizations: An Experience at UNL. In Virtual Enterprises and Collaborative Networks (L. M. Camarinha-Matos, Ed.), pp 579-588, Springer: Boston.

Camarinha-Matos, L. M.; Cardoso, T.; Klen, E.; Afsarmanesh, H., 2005. A study of VO, VBE and PVC curricula, Deliverable D71.2, ECOLEAD project, March 2005, www.ecolead.org.

Garita, C., 2004. A case study of VO education in Costa Rica. In Virtual Enterprises and Collaborative Networks (L. M. Camarinha-Matos, Ed.), pp 589-596, Springer: Boston.

Gloor, P.; Paasivaara, M.; Schoder, D.; Willems, P., 2006. Correlating performance with social network structure through teaching social network analysis. In Network-centric collaboration and support frameworks (L.M.Camarinha-Matos, H. Afsarmanesh, M. Ollus, Ed.s), pp 265-272, Springer: Boston.

Goranson, H.T., 1999. The Agile Virtual Enterprise – Cases, metrics, tools (Quorum Books).

Klen, E., Cardoso, T., Camarinha-Matos, L. M., 2005. Teaching Initiatives on Collaborative Networked Organizations, in *Proceedings of 38th CIRP - International Seminar on Manufacturing Systems*, May 16-18, Florianópolis-SC, Brazil.

Haugen, J., Hussein, B. A., Solbjørg, O., Andersen, B., 2002. Pedagogic Approaches for Training and Education (Distance Learning) in the Extended enterprise, GEM deliverable D2.1, Dec 2002. http://www.sintef.no/static/tl/projects/gem/documents/D2.1.pdf