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Computational Representation of Collaborative Learning Flow Patterns using IMS Learning Design

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ABSTRACT

The identification and integration of reusable and customizable CSCL (Computer Supported Collaborative Learning) may benefit from the capture of best practices in collaborative learning structuring. The authors have proposed CLFPs (Collaborative Learning Flow Patterns) as a way of collecting these best practices. To facilitate the process of CLFPs by software systems, the paper proposes to specify these patterns using IMS Learning Design (IMS-LD). Thus, teachers without technical knowledge can particularize and integrate CSCL tools. Nevertheless, the support of IMS-LD for describing collaborative learning activities has some deficiencies: the collaborative tools that can be defined in these activities are limited. Thus, this paper proposes and discusses an extension to IMS-LD that enables to specify several characteristics of the use of tools that mediate collaboration. In order to obtain a Unit of Learning based on a CLFP, a three stage process is also proposed. A CLFP-based Unit of Learning example is used to illustrate the process and the need of the proposed extension.

Keywords

CSCL, Collaborative Learning Flow Patterns, Computational representation, IMS Learning Design.

Introduction

The application of Information and Communication Technologies in order to enhance education has always been present. The Computer Supported Collaborative Learning (CSCL) domain is based on a new and strongly interdisciplinary paradigm of research and educational practice (Koschmann, 1996). Its main features include highlighting the importance of social interactions as an essential element of learning (Dillenbourg, 1999), as well as the role of participatory analysis and design of the whole community when creating new technological environments. CSCL applications have to include support for collaborative activities and to offer the functionality desired by the set of potential actors that can participate in collaborative learning situations (teachers, students, and pedagogy experts, among others). The effort involved in the development of useful CSCL applications is only justified if they can be applied to a large number of learning situations and if they can survive the evolution of functional requirements and technological changes (Roschelle et al., 1999).

The creation of an environment that consists of modular integrated tools would provide great benefits for the development of reusable, flexible, and customizable CSCL applications. In order to achieve these requirements the authors have been exploring some enabling technologies, namely CBSE (Component-Based Software Engineering) (Dimitriadis et al., 2003) and SOC (Service-Oriented Computing) (Bote-Lorenzo et al., 2004). Those previous works have shown that reusability, flexibility and customization largely depends on a proper identification and dimensioning of tools (components, services, blocks, modules…). The fulfilment of this task largely depends on how the principles of the domain of interest are understood by software developers. In CSCL this problem is particularly important due to the big gap among abstractions used by experts in Collaborative Learning and those used by software developers. Traditional efforts for establishing a common ground among experts in the Collaborative Learning domain and software developers include top-down and bottom-up approaches. However, the blocks identified by the top-down approach are very generic and difficult to use in concrete scenarios. On the other hand, the blocks identified by the mining of existing CSCL applications (bottom-up approach) are biased towards specific situations, so they are difficult to be reused.

The authors' experience (Dimitriadis et al., 2003) shows how the intermediate approach of Collaborative Learning Flow Patterns (CLFPs) arises as a promising alternative for identifying reusable CSCL tools. Identifying and collecting best practices and formulating them as design patterns are a rather new and promising

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approach in e-learning. Some projects which follow this objective are (E-LEN, 2004; PPP, 2005; TELL, 2005). In this context, patterns reflect the experience of experts in a particular educational domain (e.g. collaborative learning) and they capture common solutions to recurrent problems (Alexander, 1997) in an educational scenario. Therefore, design patterns (particularly CLFPs) based on sound research can help educators and educational content developers in the design of potentially effective e-learning scenarios.

A CLFP can be understood as a way of describing a collaborative learning technique. Collaborative learning techniques dictate common ways of structuring interactions among participants in different activities, as well as the information they interchange. Thus, CLFPs actually derive from practice (didacticism used in the practice) rather than from general learning theories (Aronson & Thibodeau, 1992; Fablusi P/L, 2005; Johnson & Johnson, 1999; NISE, 1997), i.e. they represent methods (or "recipes") that have been extensively tested and applied in a broad range of different settings and on which there are many publications on research or practical results (Strijbos et al., 2004). These methods pre-structure collaboration in such a way that productive interactions are promoted, so that the potential effectiveness of the educational situation is enhanced (Jermann et al., 2004). That is to say, CLFPs formulate best practices in structuring the flow of types of learning activities (and to some extent types of tools) involved in collaborative learning scenarios. These types of activities are mostly collaborative, but the learning flow suggested by a CLFP could include individual activities as well. The term "learning flow" is used in the learning domain in analogy to the term "workflow" of CSCW. Both refer to the coordination at activity level (activity-level coordination), which describes the sequencing of activities that make up a process (Ellis & Wainer, 1994).

CLFPs are identified and described by collaborative learning practitioners using a formalism based on natural language. This fact makes the information provided by CLFPs difficult to be used by computer-based applications such as authoring tools that could help teachers to select and integrate the CSCL tools they need in order to support a collaborative learning class. Therefore, a computer-oriented representation or "formalization" of CLFPs is required so as to broaden their applicability in CSCL scenarios. It should be underlined that this paper refers to the term "formalization" in the sense of being able to describe CLFPs using a notation or language so that automatic processing is possible.

Hence, to formalize these CLFPs we are exploring the use of IMS Learning Design (IMS-LD or simply LD) (IMS, 2003). This educational modelling language expresses the flow of any learning process in the context of a Unit of Learning in a formal way, so that these learning designs (an LD compliant learning design or simply a Learning Design or an LD) can be processed automatically (Koper & Tattersall, 2005). This automatic processing is precisely one of the requirements IMS-LD specification is intended to fulfil (requirement R4 included in section 2.1 of IMS Learning Design Information Model (IMS, 2003)). Furthermore, it states that it provides a means of expressing many different pedagogical approaches. However, within the formalization of CLFPs, we have found some limitations in reflecting learning experiences that are group-based. Thus, this paper proposes an extension to IMS-LD in order to solve these deficiencies. This extension allows specify features of tools that mediate collaboration and, implicitly, collaborative learning characteristics of the learning activity that uses these tools.

Summarizing, the objectives of the paper are: to explore the support of IMS-LD for computationally representing Collaborative Learning Flow Patterns so that they can be processed by software systems, to propose an extension to IMS-LD that facilitates the description of CSCL tools and to indicate the steps that an authoring tool can implement in order to create CLFP-based Units of Learning (IMS, 2003), that are potential effective designs of collaborative learning scenarios.

Therefore, this paper is structured as follows: In the following section, the concept of CLFP and the theoretical foundations that motivate their proposal are introduced. It is followed by an analysis of the requirements for the description of collaborative learning scenarios, and particularly, CLFP-based situations. This section also discusses and proposes an extension to the IMS-LD specification. The process that can be followed in order to obtain Units of Learning based on CLFPs, the illustration of the process by a CLFP-based Unit of Learning example and an introduction to two systems based on the ideas proposed in the paper are presented next. The paper ends with some concluding remarks and some pointers to future work.

Collaborative Learning Flow Patterns

Five main advantages for adopting a patterns approach in e-learning design are pointed out in (E-LEN, 2004). One of these advantages is that patterns can facilitate communication within interdisciplinary and multi-

perspective teams (technologies, teachers, educational designers and subject-matter experts). Therefore, in terms of CSCL domain, patterns can be used for reducing the conceptual gap between the collaborative learning field and the software development world. This fact, as it has been motivated in the introduction, might be helpful in advancing towards the desired goal of obtaining reusable, customizable, and integrated CSCL software tools.

Patterns can be identified and constructed using mainly two methodologies: inductive pattern mining (from specifics to generalizations), by analyzing common solutions in a set of educational situations, or deductive pattern mining (from generalisations to specifics), by capturing the essence of generic models for solutions to recurrent problems that experienced learning designers identify (Baggetun et al., 2004). The second method is the approach taken in order to formulate CLFPs. These patterns represent commonly used techniques that are repetitively used by practitioners when structuring the flow of types of learning activities involved in collaborative learning situations.

One very well-known example in this sense is the "Jigsaw" structure (Aronson & Thibodeau, 1992; Clarke, 1994). Briefly, this technique propose that *in order to solve a complex problem that can be easily divided into independent sub-problems, each participant in a (small) group ("Jigsaw Group") studies or work around a particular sub-problem. The participants of different groups that study the same problem meet in an "Expert Group" for exchanging ideas. These temporary groups become experts in the subproblem given to them. At last, participants of each "Jigsaw group" meet to contribute with its "expertise" in order to solve the whole problem.* Some of the educational objectives this method favors are: to promote the feeling that team members need each other to succeed (positive interdependence), to foster discussion in order to construct students' knowledge and to ensure that students must contribute their fare share (individual accountability).

Depending on the granularity or the detail level, pre-structuring collaboration can be accomplished in a coarse-grained process level (i.e. phases or flow of activities) and/or fine-grained level of detailed learning actions (actions within an activity). As it has been already mentioned and can be noticed in the example, the granularity on which the paper is focused is related to collaborative learning flows. That is, to the sequencing of types of activities (collaborative and not) that comprise a collaborative learning situation. It is important to underline that the emphasis of the CLFPs lays on the learning flow and not on other aspects of the collaborative learning domain such as group formation schemes, evaluation or scaffolding methods, etc. Best practices in all these aspects could be also suitable of being formulated as design patterns. Furthermore, all these patterns and their interrelations might be arranged in a pattern language for CSCL. Related works are described in (Avgeriou et al., 2003), in which a pattern language for LMSs (Learning Management Systems) is proposed, and in (Goodyear et al., 2004), in which some efforts in order to build a pattern language for what they call Network Learning are presented.

CLFPs are represented according to a formalism, shown in Table 1, that enlarges the one previously described for "Collaboration Design Patterns" introduces in (DiGiano et al., 2002). That table also shows two examples of a CLFP defining well-known practices in collaborative learning: *Pyramid* (or Snowball) and *Brainstorming.* Others examples, for instance *Jigsaw* CLFP (Aronson et al., 1992) is presented in (Dimitriadis et al., 2003). Other CLFPs are Simulation CLFP (Fablusi P/L, 2005) and TAPPS (Thinking Aloud Pair Problem Solving) CLFP or TPS (Think-Pair-Share) CLFP (NISE, 1997). Since CLFPs collect knowledge from collaborative learning practitioners, as it can be appreciated in Table 1, they do not necessarily contain any technical information.

CLFPs can also be collectively used forming CLFP hierarchies in order to define more complex collaborative learning flows. CLFPs can be *combined*: a particular phase of a CLFP can be structured according to another CLFP (that can be eventually the same); or simply *concatenated*: some phases of a learning design are structured according to a CLFP and other (separated but consecutive) phases of the learning design are structured using another CLFP (that can be eventually the same).

An example of combining CLFPs is the following. The example is a two-hour experience consisting of the collaborative reading and discussion of a technical paper (long and difficult enough). Students are divided in groups of three and each group is organized according to the Jigsaw CLFP in order to read the paper. For the final step of the Jigsaw ("experts" share their expertise and agree on a final proposal) Brainstorming CLFP is employed. Final proposals simply consist of a list of the ten most important ideas found in the paper. Then, the different groups start working according to the Pyramid CLFP so as to agree on a final and unique list of 10 ideas.

Table 1. CLFP structure, Pyramid and Brainstorming CLFPs examples

Facet	Explanation	Example #1		Example #2	
Name	Name of the CLFP	**Pyramid**		**Brainstorming**	
Problem	Learning problem to be solved by the CLFP	Complex problem, usually without a specific solution, whose resolution implies the achievement of gradual consensus among all the participants		Problem, whose solution is the generation of a large number of possible answers in a short period of time. Explanations, evaluations and questions are not permitted as the ideas are generated	
Example	A real-world learning activity capable of being structured according to the CLFP	Collaborative proposal of the design of a computing system where each participant contributes with a design that is subsequently compared with other contributions and refined		Collaborative creation of a collection of possible software technological solutions for the implementation of a software system with a set of determined requirements	
Context	Environment type in which the CLFP could be applied	Several participants facing the collaborative resolution of the same problem		Several participants facing the generation of a large number of ideas	
Solution	Description of the proposal by the CLFP for solving the problem	Each individual participant studies the problem and proposes a solution. Groups of participants compare and discuss their proposals and, finally, propose a new shared solution. Those groups join in larger groups in order to generate new agreed proposal. At the end, all the participants must propose a final and agreed solution		The teacher asks a question that has a large number of possible answers. Students in the same group write down (using a determined floor control) their answers. This process continues until the students run out of possible solutions. After the brainstorming, the teacher gives time for the team to review and clarify their ideas. If needed, the group can present the ideas generated to the rest of the class	
Actors	Actors involved in the collaborative activity described by the CLFP	- Teacher - Learner		- Teacher - Learner (- Writer)	
Types of Tasks	Types of tasks, together with their sequence, performed by the actors involved in the activity.	**Learner:** 1.Access to the information 2.Individual study of the problem 3.Individual solution proposal [REPEAT 4.Group formation 5.Group discussion 6.Common solution proposal] (Until only one group remains) 7.Process self-evaluation	**Teacher:** 1.Global problem definition 2.Provision of useful information 3.Group dimensioning 4.Decisions about control of time 5.Activity progress monitoring 6.Result evaluation	**Learner:** 1. Listening or reading the question the teacher proposes 2. Writing down their answers or one person is designated to record the ideas as they are given 3. Review and clarification of their ideas (optional) 4. Presentation of the ideas generated in the group to the rest of the class (optional) 5. Process self-evaluation	**Teacher:** 1. Question that has a large number of possible answers. 2. Control of the time or that students are run out of ideas 3. Decisions about time for the team to review and clarify their ideas (optional) 4. Supervision of the presentations of the students (optional) 5. Result evaluation
Types and structure of Information	Description of the types of information identified in the collaborative activity and how they are related	- Input information needed for global problem resolution - Intermediate resolution proposals - Global problem resolution proposal - Correct global problem resolution (optional)		- Input information about the question (optional) - Record of ideas - Result information about the review (optional)	
Types and structure of Groups	Description of the types of groups of learners identified and how they are related	- Growing pyramid groups		- Brainstorming groups - Whole class	

Table 1 shows how a CLFP provides software developers with information about the flow of learning activities types that are expected to occur during a collaborative learning scenario based on that CLFP. Using this information, software developers can identify what type of CSCL tools could be needed in order to support collaborative learning scenarios compliant with the same CLFP (e.g. discussion forums, collaborative shared editors). Moreover, software developers can be confident on the fact that an important subset of those tools could potentially be reused in the support of several of those scenarios. That is why we propose CLFPs as a good option for software developers to obtain information from the collaborative learning domain and, at the same time, fulfil the goal of reusability and adaptability of CSCL applications.

Furthermore, the information provided by CLFPs could be used by software-based authoring applications that would guide practitioners (teachers, particularly novice ones) to create learning designs and, as a consequence, to select and integrate the CSCL tools that they need in order to support a collaborative learning classroom. This assistance reduces the complexity of the learning design process and guarantees significantly effective results, since the guidance is based on the reuse of best practices in collaborative learning. However, this is not a trivial problem: the description of CLFPs is based on natural language due to the fact that non-technical people propose them. That means that software tools cannot process CLFP definitions.

Therefore, the following section explores the process and the suitability of the use of IMS-LD specification towards a more formal description. Another approach could have been the use of a workflow process language as it is proposed in (Vantroys & Peter, 2003). However, those languages do not allow define some necessary aspects of a learning process such as the educational objectives.

IMS-LD Extension for CSCL

E-learning standardization efforts are now moving from content delivery resources to Educational Modelling Languages (EML), which are focused on the performance of individual and group learning activities (Caeiro et al., 2003). Learning Design, realised by the IMS Global Consortium, is the most accepted EML at present. IMS-LD states to be a pedagogically neutral language that can describe any learning process in a formal way in the sense that they can be processed automatically by software tools (IMS, 2003). A *Learning Design* is a description of a *method* enabling learners to attain particular *objectives* by performing *learning activities* in a certain order in the context of a learning *environment*. The environment consists of the appropriate *learning objects* and *services* to be used during the performance of the activities. A method contains the *play*, which is modelled according to a theatrical play with *acts* and *role-parts*.

IMS Learning Design for CSCL

IMS-LD affirms that it supports group and collaborative learning of different kinds. It enables the design of processes that include several roles, each of which can be played by several people (a group). A collaborative learning experience can be described by associating multiple people and/or multiple roles to the same learning activity. In addition, IMS-LD enables their activities to be specified in coordinated learning flows. Therefore, IMS-LD seems to be a reasonable candidate as a language with which to formalize the CLFPs.

However, while a main feature of CSCL applications is the set of mechanisms that support collaboration, IMS-LD provides no means to specify how the members of a group interact within each learning activity**,** i.e. to determine the types of interaction promoted by the activity: discussion, argumentation, exchange of ideas, etc. (Strijbos et al., 2004). It only states that if multiple individuals are to collaborate or work together at the same time, this has to be done through a *service* in their assigned environment which supports this collaborative capability (IMS, 2003). Therefore, the concept of service is central in IMS-LD for CSCL. An IMS-LD service specification describes the characteristics of a "tool" that supports a learning activity. When applying a Learning Design to an actual learning scenario the learning designer must specify the resources that, at last, provide the implementation of the defined services, thus obtaining a so-called Unit of Learning. These resources range from a simple blackboard or a paper sheet to a complex e-learning or CSCL application (e.g. collaborative editors, document sharing tools, discussion forums, shared blackboards, etc.).

In this point, it is necessary to remember that since a service (included in an environment) is referenced in one or more activities, the specification of the service is part of the definition of each activity. Activities are not completely designed without environments. Thus, when a service supports collaboration, the activities that use this service are collaborative.

Extension to the IMS-LD Service Element

IMS-LD only proposes and defines four basic services, two of which are (to some extent) collaborative: discussion forum and e-mail. IMS-LD states that other needed services should be specified by the designers of learning scenarios. The problem is that IMS-LD does not permit the aforementioned designers to describe collaboration-related capabilities when defining (or configuring) a service (Hernández-Leo, 2003). Some of these features are:

- Type of *awareness* information (updated information about other people's presence, location, state of the task, etc.) needed and provided by the service and from what roles of the LD is needed to provide information, so that an understanding of the work of others provides the adequate context for each own work (Gutwin & Greenberg, 1999). Possible values of the type of awareness are *identity* (who is participating?), *action* (what is she/he doing?), *location* (where is she/he working), etc.
- *Floor control* policy that guides learners actions. If it is *fixed* and previously established by the teacher/designer or it is *dynamic* (it is not previously established) or, simply, there is not any floor control policy.
- The type of *communication skills* that is to be used in the collaboration to be supported by the tool defined in the service: writing, speaking, gesticulation, drawing…
- The roles (of the LD) that *participate* in the same instance of the service.
- If the whole workspace facilitated by the collaborative tool described in the service is public or shared (all the participant have access to the workspace), or private (each participant only has access to his/her workspace) or a mixed workspace (Ellis et al., 1994).
- The *type of interaction* that is supported by the service. This element distinguishes between *direct interactions* with a source and one or more receivers (e.g. a contribution to a discussion in a chat), *indirect interactions*, mediated by a shared object (such as a document or a piece of a puzzle) and *participation-oriented interactions,* that allow to annotate participations of an actor in situations where no receptor has been identified (e.g. a post in a discussion forum without answers) (Martínez et al., 2003).

In this context we propose a preliminary extension to the IMS-LD service description consisting of the definition of a special type of service, called *groupservice*, whose main characteristics (some of them are optional) are summarized according to the capabilities aforementioned in Figure 1. It is again noteworthy that the characterization of these elements is to a large extent part of the description of a collaborative learning activity.

This generic characterisation of collaborative services, together with the definition of learning flows provided by IMS-LD, enable scenarios in which existing CSCL tools can be selected and integrated in order to support a complete (and potentially complex) set of learning activities. Furthermore, and thanks to the language provided by IMS-LD, which can be processed by software systems, this selection and integration of CSCL tools can be automatically (or almost automatically) performed thus hiding software engineering problems to learning designers (e.g. teachers).

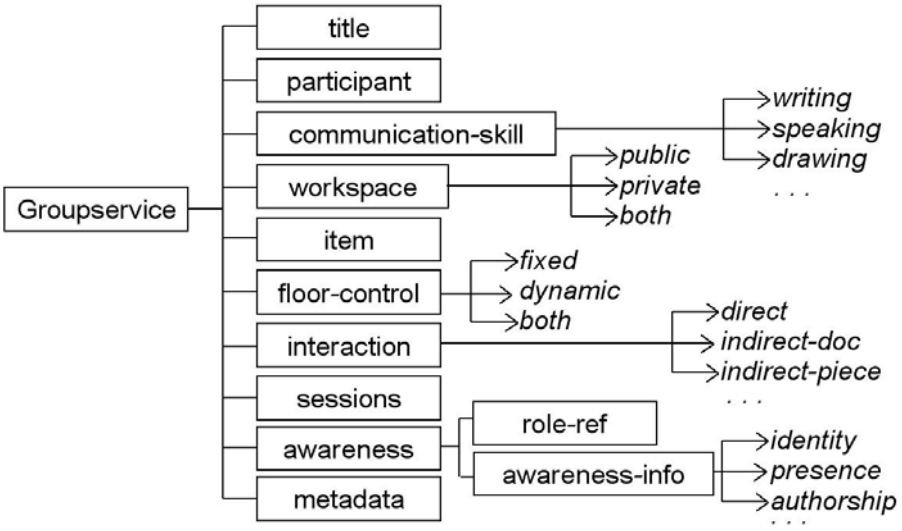


Figure 1. Scheme of the proposed extension to the IMS-LD service element

The proposed extension to IMS-LD is also useful in order to achieve a computational representation of CLFPs (Hernández-Leo, 2003). In this sense, a CLFP can be understood as an "incomplete" Learning Design that has to be customized in order to generate a complete one. An IMS-LD definition of a CLFP includes the description of groupservices in which some of their collaborative characteristics are not specified. Nevertheless, the level of groupservice descriptions provided by a CLFP is enough for the identification of types of services needed by all the learning scenarios that could be derived from the same CLFP. This fact, in a CSCL environment, helps software developers to decide what characteristics a CSCL tool should possess in order to be potentially reused in the different learning scenarios that are compliant with the same CLFP. The next section presents the process that can be followed in order to obtain Learning Designs and Units of Learning (UoL) based on CLFPs and illustrates the process with an example.

Units of Learning Based on CLFPs

Creating successful designs of collaborative learning scenarios and, particularly, Learning Designs from scratch is a complex task from a pedagogical point of view (Koper & Tattersall, 2005). Since CLFPs are best practices in collaborative learning and are computationally represented with IMS-LD, it could be possible to easily achieve a potential effective collaborative Unit of Learning (IMS, 2004) if its integrated LD is based on a CLFP. That is, the roles, the types of activities and the learning flow of the Learning Design are a particularization of a CLFP; and the CLFP-based Unit of Learning consists of the previous CLFP-based Learning Design and a set of particular resources that depend on a concrete learning scenario.

From CLFPs to Units of Learning

It is possible to establish links between the facets of the CLFP structure (see Table 1) and the elements of IMS-LD, as a result the formalization of CLFPs using IMS-LD can be to certain extend semi-systematized. For instance, the *types of tasks* of a CLFP can be translated to the IMS-LD *learning* and *support activities*. Although in a subtle way, *actors* and *type of groups* can be described by the IMS-LD *role*. The *types of information* a CLFP requires can be mapped to IMS-LD *properties* or IMS-LD *learning objects* depending on whether the information is to be produced or modified during the Learning Design or it is input information, respectively. The solution a CLFP suggests is basically a collaborative learning flow, which in IMS-LD is specified in the *method*.

The process that could be followed in order to achieve a Unit of Learning based on a CLFP is illustrated in Figure 2. This three-stage process is to be implemented by authoring tools that would guide teachers to particularize and customize a CLFP to a Unit of Learning that satisfies a concrete learning situation. The first step is the formalization of a CLFP using IMS-LD, that is to say, the edition of an IMS-LD-compliant XML document that describes the CLFP. This edition should be made following the indications that imply the links between the IMS-LD elements and the CLFP features described in the previous paragraph. Since an IMS-LD document that formalizes a CLFP is an incomplete Learning Design (a CLFP generalizes best collaborative learning structuring practices), the second step involves the particularization of the preceding document, so as to detail all the elements of a complete Learning Design. When the actual resources that are to be used during the running of the CLFP-based Learning Design are determined and packaged or referenced within a content package (IMS, 2004), a CLFP-based Unit of Learning is achieved. Next subsection illustrates this proposed process by means of an example.

Table 1 included the example of the Pyramid CLFP, where several individuals join successively in larger groups in order to reach an agreed solution to the same problem. The Pyramid CLFP has been applied by the authors to the specification of a Learning Design that supports a course on computer architecture (AO, from the Spanish name of the course) for Telecommunications Engineers in our University. The learning flow of the CLFP can be expressed in a *play* of the IMS-LD method. The play consists of a sequence of *acts*. As it is exemplified in Figure 3 each act represents a pyramid level, i.e., whenever people join in a larger group to compare and discuss their proposals, and propose a shared solution. In each act, different activities are set for the different roles (learner, teacher and evaluator) and are performed in parallel. (laox01, laox02, etc. are the names of the AO laboratory groups.) Note that this play represents a particularization of the flow of task types of the Pyramid CLFP pointed out in Table 1.

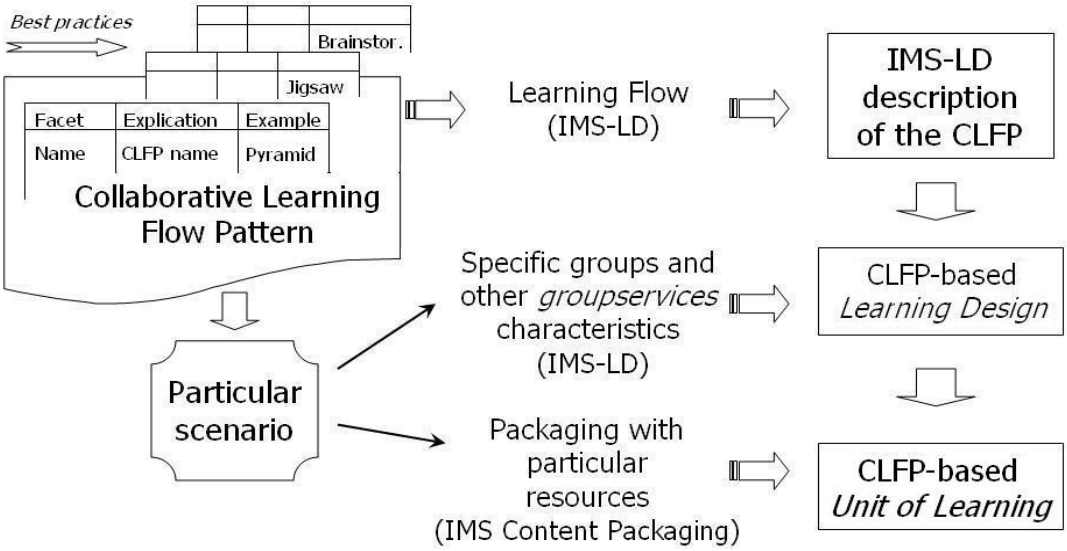


Figure 2. Process for Obtaining CLFP-based Units of Learning

Pyramid CLFP-based Unit of Learning Example

Table 2 shows how this example of collaborative learning structuring can be formalized with IMS-LD using the three-stage process illustrated in Figure 2. Column 1 of the table illustrates the IMS-LD description of a Pyramid CLFP learning activity (first step of the three-stage process). This computational representation of a CLFP is supposed to be available to the teachers. When an act is completed, the next act starts until the completion requirements for the Learning Design are met (last level of the pyramid). The collaboration of the individuals of each group in the pyramid is mediated by a type of service described as a *groupservice*, i.e., using the proposed extension. Column 2 represents the teacher customisation of the Pyramid CLFP IMS-LD description for this particular course. This is an example of a Pyramid CLFP-based Learning Design (second step). When the teacher determines the binding of this Learning Design with concrete CSCL tools, an example of a Pyramid CLFP-based Unit of Learning is completed (third step). Column 3 shows a Unit of Learning (UoL) in which a particular implementation of a *groupservice* is referenced within the CLFP-based Learning Design. This resource is a collaborative labelling of parameters tool that enables the discussion and agreement of some computer cache design parameters. (Note that in its description or configuration participant roles, awareness issues, floor control characteristic, etc. are included.) Thus, table 2 illustrates the three-stage process for obtaining a Unit of Learning based on a CLFP.

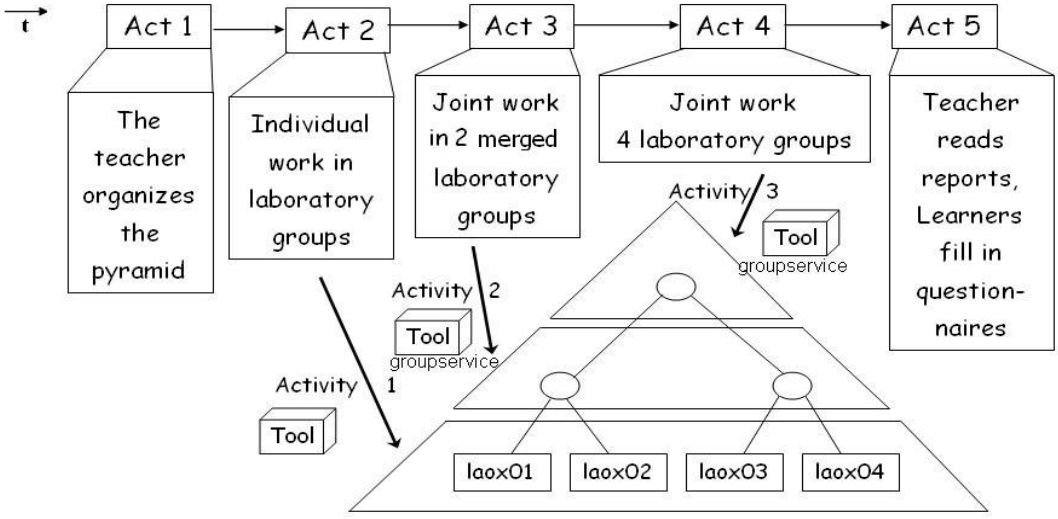
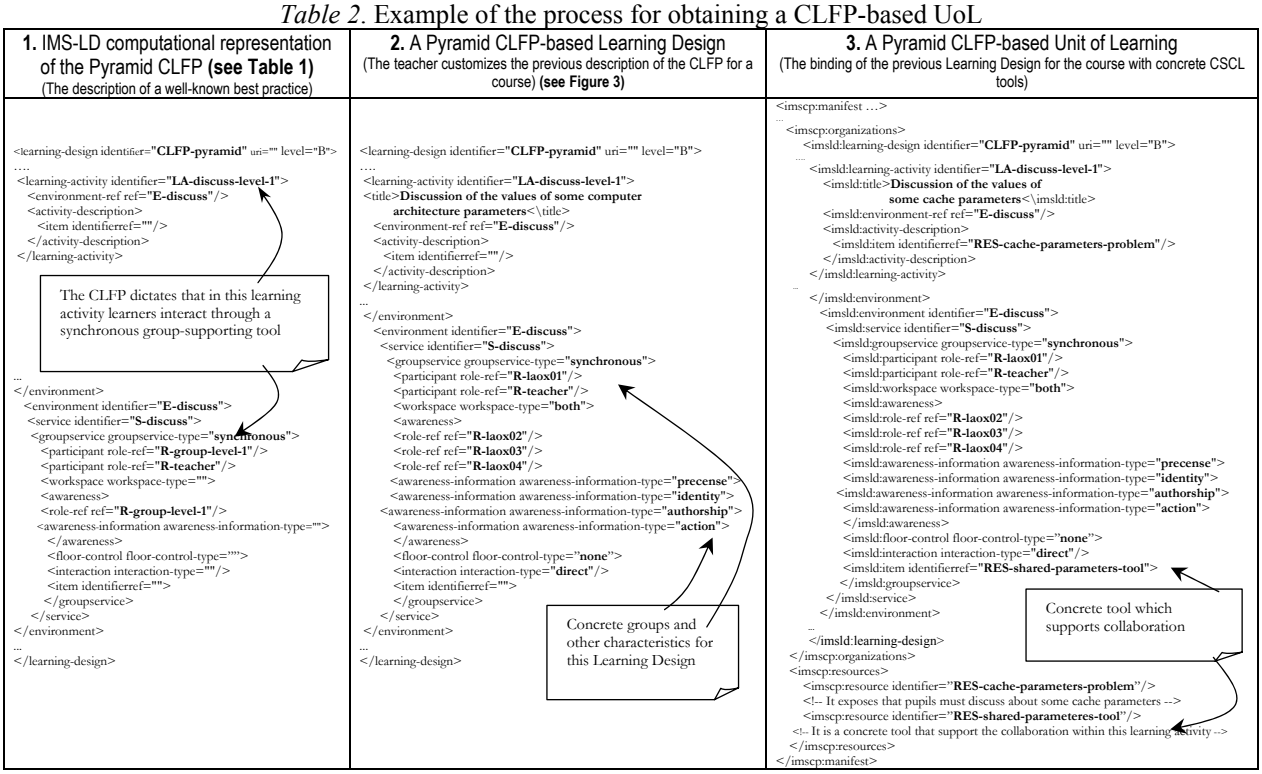


Figure 3. Play of the Pyramid CLFP-based Learning Design

Table 2. Example of the process for obtaining a CLFP-based UoL



Implementing and evaluating the proposals

The authors have already developed two CSCL systems based on the ideas proposed in the paper.

The first of these CSCL systems is an authoring tool: *Collage* (COLlaborative LeArning desiGn Editor) (GSIC, 2005), which implements the proposed three-stage design process (see Figure 2), is capable of guiding collaborative learning designers in the process of creating their own Learning Designs by starting from existing CLFPs already formalized with IMS-LD. Thus, it helps practitioners (teachers, particularly novice ones) to more easily produce potentially effective collaborative LDs, as they reuse best practices in the field.

The second system is devoted to the *execution or enactment* problem and is called *Gridcole* (Bote-Lorenzo et al., 2004). *Gridcole* uses the generic characterisation of collaborative services proposed in the paper. This system is capable of interpreting LDs and setting up the technological environment needed to support all the (collaborative) learning activities included in the design (a CLFP-based LD). The technological environment consists of an integration of software tools which can be specified as IMS-LD services in the LD (e.g. a collaborative tool from which several instances should be created because in runtime multiple groups use this tool separately from other groups) or not (e.g. they can be tools for individual work modelled as learning objects). These tools are provided by third parties in the form of the so-called grid services that follow Service-Oriented Computing paradigm (Papazoglou & Georgakopoulos, 2003).

Several evaluation studies with real users have been performed with both *Collage* and *Gridcole*. In addition to the evaluation of the systems themselves those studies also tried to obtain feedback on the utility and validity of the underlying proposals presented in this paper. Evaluation studies with *Collage* can illustrate the utility of the design process based on CLFPs as well as the validity of their computational representation using IMS-LD as a way of enabling computer-based interpretation. On the other hand, evaluation studies with *Gridcole* are intended to provide further evidence on the utility of script-guided learning designs and the validity of the proposed extension to IMS-LD so as to deal with collaborative learning tools.

For the studies, a simplification of the mixed qualitative-quantitative method proposed in (Martínez et al., 2003) for the evaluation of collaborative learning situations has been applied. Briefly, this method consists of three phases: elaboration of a "scheme of categories" regarding those aspects to be evaluated; data collection from different qualitative and quantitative sources; and data analysis combining qualitative and qualitative analysis techniques as well as triangulating the results from the different analysis so as to obtain conclusions on each

previously identified category. The data sources that were used in the evaluation studies described herein include questionnaires filled up by the users, in-place direct observations performed by experts in evaluation, and meetings with subsets of the users (*focus groups*) to collect their opinions, impressions, recommendations, etc. on their involvement in the studies.

In the following subsections on the different evaluation studies we initially present the context of the courses that correspond to them, while later we proceed with the description of the evaluation results and the related discussion.

Collage evaluation studies

For *Collage* two evaluation studies were performed. The first one involved three real teachers of the Faculty of Education of our University. These teachers are involved in an undergraduate course on "Use of Information and Communication Technologies in Education". This course considers classes of 40 students (maximum). As part of the activities of the course pairs of students work on one particular topic (out of three proposed by the teachers). The input resources for the work (mainly electronic documents) are available in the Synergeia system (ITCOLE, 2005). Each pair of students creates a conceptual map regarding their topic after having read the input material. They employ the conceptual map tool of Synergeia, and upload the resulting map again to Synergeia. Half of the pairs that have worked on the same topic join and compare their conceptual maps (note that the conceptual maps are all available in Synergeia). Afterwards, and according to the contents of the compared conceptual maps, students generate a draft document (following a provided template), and upload it to Synergeia. All pairs with the same topic join and compare and discuss the draft documents generated in the previous phase. After the discussion they create an agreed report according to the same previous template, and upload the document to Synergeia. After that, three (or four) pairs of students with different assigned topics, join and discuss their generated reports. Finally, each one of these big groups creates a new final report. As it can be seen, the organization of this scenario (one month in duration) reflects a mixture of the structuring ideas of the Jigsaw and Pyramid CLFPs (see table 1).

The second *Collage* evaluation study involved two of the authors of this paper that tried to use *Collage* to obtain IMS-LD designs corresponding to collaborative learning experiences in their courses as University teachers. The first teacher is involved in an undergraduate course on "Operation, Administration, and Maintenance of Communication Networks" at the School of Telecommunications Engineering of our University. The part of the course he intended to design using Collage consisted of a two-hour session in which students have to collaboratively read and discuss a technical paper on the subjects of the course. Students are divided in groups of three and each group is organized according to a Jigsaw. Therefore, each student of each group reads one part of the paper. The students from different groups that have read the same part ("experts") join to discuss on what they read and to exchange ideas and try to solve doubts. Afterwards, each original group meets again so that each member explain to the others his or her part of the paper. During this last stage, each group initiates a Brainstorming in order to agree on the 10 most important ideas of the paper. Once each group has its list of 10 ideas, pairs of groups join to exchange them and to agree again in a unique new list. The resulting groups join again in pairs to perform the same task. And this process is repeated again until two large groups remain. This is an example of a Pyramid CLFP.

The second teacher deals with a graduate course on "Advanced Telematic Systems" at the School of Telecommunications Engineering of our University. In this case, students try to propose a research question on a complex interdisciplinary field that involves several keywords. The students are therefore organized in a Jigsaw in which the "experts" are devoted to the study of some of the keywords. The research questions proposed by the "experts" are afterwards discussed and merged in the Jigsaw groups. This process also takes two two-hour sessions. The whole process requires tools for individual work, such as editors, or for collaborative work, such as document sharing, discussion, etc.

Both *Collage* evaluation studies consisted in a two-hour session during which these five teachers had to separately use *Collage* to try to obtain an IMS-LD document reflecting the design (activities, flow, resources, etc.) of their courses (as previously described). All of the teachers are collaborative learning practitioners with previous knowledge on the techniques formulated in the CLFPs that *Collage* provides. The three teachers of the first study have no knowledge on IMS-LD, and they have not used other learning design authoring tools. On the other hand, the two teachers of the second study have minor knowledge on IMS-LD and that was their first contact with Collage.

After applying the simplified evaluation method to both studies, the results were quite similar. The scheme of categories for analysis included "user profiles", "tool usage", and "suggestions". Although the evaluation of *Collage* as a tool is out of the scope of the paper, it is worth mentioning that the users found it intuitive and user-friendly. With respect to the usefulness of CLFPs and the design technique proposed in section "IMS-LD Extension for CSCL" and promoted by *Collage* the explicit opinion of the users was quite illustrative. For instance, one of the teachers said: "It helps to think in terms of collaborative learning and its previous arrangement". A second teacher stated: "It helps to structure a complex learning design and promotes times and resources planning". Finally, another teacher said: "It enables the generation of contextualized learning processes according to the needs of each situation". At the same time, all the users found that the way *Collage* presented and used the CLFPs was very similar to their previous understanding of the techniques these CLFPs formulate. That is an indication that the IMS-LD based formulation of the CLFPs has no significant loss of information.

As another indication of the usefulness of the CLFPs and the proposed design process, it is worth pointing out that the evaluation studies involved the creation of learning designs including activities with very different features: synchronous and asynchronous, face-to-face and distant, computer-supported and non computer-supported (even blended situations), shorter (two hours) and longer (one month), etc.

Nevertheless, several drawbacks of Collage and its underlying design process were raised. Mainly: previous knowledge and understanding of CLFPs is needed before authoring (Collage provides detailed explanations and examples of use for each one of the provided CLFPs) and it is not possible to add complementary activities to those prescribed by the CLFPs.

In spite of those drawbacks, the results of these field studies have given us the first real evidences on the utility and validity of our proposals although, as it will be discussed in the "Conclusions" section, deeper and longer evaluation studies should be undertaken in order to further support our claims.

Gridcole evaluation studies

With respect to *Gridcole* other two evaluation studies were performed using the current prototype of the system (Bote-Lorenzo et al., 2004; Bote-Lorenzo, 2005). These studies involved two different types of users but the same collaborative learning scenario. The scenario consists of a four-hour session of the "Computers Architecture" undergraduate course at the School of Telecommunications Engineering of our University. This is a project-based course in which students act as consultants of different types of clients with their own computing requirements. During this particular session, students are intended to use a benchmarking tool to analyse performance features of a set of available computing systems in order to decide which one is the most suitable for their particular clients. In this case, *Gridcole* acts as a Learning Management System (LMS) that is tailored according to an IMS-LD script that uses the collaborative extensions proposed in this paper. That script also specifies which collaborative or non-collaborative learning tools the students should use during the session. The tools, in the form of grid services, are offered by *Gridcole* in an integrated fashion to the students.

The first study involved four former students of the course that are currently researchers at out School but in different research areas than ours. The second study involved eight real students of the course.

For both studies, students are divided in groups of four. In a first step, each student works individually studying a set of documents related to the activity. Then, each student uses a benchmarking tool to obtain additional information on the evaluated systems. After that, each student writes a report containing his or her justified proposals. Then, a remote collaborative phase begins in which two students exchange their reports, discuss on them, perform new benchmarks if needed, and write a joint report. A chat tool, a benchmarking tool, and an editor are used throughout the session. As it can be appreciated, this learning design uses the ideas of the Pyramid CLFP.

The same evaluation process that was applied to *Collage* was used for these studies. Different categories were analysed using the obtained quantitative and qualitative evaluation data. Among these categories it is interesting to underline that most of the students (50%, 75% in the case of former students) considered that *Gridcole* helped them "quite a lot" to perform the activities in collaboration with the other students (25% said "a lot", and 25% said "some"). Among the reasons for this statement, the students pointed out the fact that *Gridcole* guided them step by step (scripting advantages). Also, a 75% of all the students said that the collaboration with the other students was "quite positive" (the other 25% said "some positive"). Nobody said "very positive" but also,

nobody indicated that the collaborative was "negative". More details on the results of these studies can be found in (Bote-Lorenzo, 2005).

From these results, it is possible to obtain new indications that CLFPs are useful for structuring collaboration. Also, that collaborative scripting (with an adequate level of prescription) enforced by a collaborative LMS may encourage effective collaboration. Finally, and although this is something not directly perceived by the users, the *Gridcole* prototype was able to handle collaborative tools thanks to the use of the IMS-LD extension proposed in this paper. More concretely and in this technological setting, when interpreting the IMD-LD learning design for the described session, *Gridcole* detected in which cases the involved tools (a chat tool, a benchmarking tool, an editor) were going to be used individually or collaboratively. As an example of the utility of this extension, from a technical point of view, *Gridcole* was able to launch and properly assign the needed instances of the tools for each case. Without the extension, *Gridcole* would have launched the same number of tool instances in both cases and thus the students would have been forced to take care of the exchange of results, their joint coherence, and their joint storage. In other words, the extension is needed for developing collaborative LMSs. The alternative with the extension is developing LMSs that might in some cases *be used collaboratively* what implies moving the collaboration management burden to their users.

Besides the above field studies, two more feasibility studies have taken place. In these studies we have shown that CLFPs and the associated collaborative extensions of IMS-LD enable the realization of new real scenarios in the courses of "Telecommunications Traffic and Management" and "Telecommunications Systems V" (Bote-Lorenzo, 2005). However, we have not obtained yet real field study results on them.

Conclusions

This paper has introduced the concept of Collaborative Learning Pattern (CLFP) as a way of collecting, reusing, and exchanging well-known and sound best practices in structuring the flow of collaborative learning activities. Also, the paper has proposed the use of CLFPs as the starting point for the process of collaborative learning design. This design process enables the reuse of existing experience in collaborative learning thus facilitating the adherence to this way of learning of new practitioners that do not need to build their designs from scratch. In addition to the above educational advantages, CLFPs are also a promising approach for establishing a conceptual common ground among collaborative learning practitioners and software developers of CSCL applications. This common ground is a prerequisite for the identification of potentially reusable CSCL software blocks.

The paper has also motivated the application of IMS-LD in order to achieve a computational representation of CLFPs. This representation would enable CLFPs to be processed by software tools such as authoring tools based on the learning design process proposed by the paper. The use of authoring tools is motivated by the complexity of the IMS-LD specification for non-technical educators. IMS-LD based learning designs (or other Educational Modelling Languages in general) are needed for guiding the behaviour of Learning Management Systems that handle all computing and network resources for giving technical support to a particular learning scenario.

In this sense, the computational representation of CLFPs using IMS-LD has shown a certain degree of IMS-LD support for the description of collaborative learning scenarios. Nevertheless, the main detected deficiency is related to the specification of learning activities involving groups which require particular tools that support collaboration. In order to solve this limitation, that would negatively impact the availability of collaborative Learning Management Systems, the paper has proposed a set of extensions to IMS-LD focused on the definition of a new type of services for supporting group collaboration. The authors are aware that the proposed extension entails a modification (addition) of the IMS-LD specification, but they consider that this is a better approach than trying to propose a completely new language. The possibility of definition of this type of services and its characteristics enlarge the set of collaborative learning activities that can be described using IMS-LD. However, the preliminary proposed extensions still have some limitations: they support very limited awareness and floor control models, and they do not allow the specification of privileged roles, among others.

Feasibility and evaluation studies of different nature have been performed with two systems that, in one way or another, are based on the ideas presented in this paper: *Collage* IMS-LD authoring tool based on CLFPs, and *Gridcole* a collaborative learning management system that uses the proposed collaborative IMS-LD extension. Results from those studies provide the first indications of the usefulness of the IMS-LD based CLFPs and the collaborative learning design process based on them in a wide range of learning scenarios, as well as the need for collaborative extensions of IMS-LD in order to introduce collaboration support in Learning Management Systems.

Several short-term activities are under way within our research group in order to enhance the above contributions. First of all, we are enlarging the set of available CLFPs (at the moment *Collage* already implements six CLFPs) provided by collaborative learning practitioners in order to deeply validate the CLFP approach itself and also in order to have a broader knowledge of concepts and principles of the collaborative learning domain. Secondly, we are currently working on the improvement and refining of the preliminary proposed extensions to IMS-LD by adding more collaborative-related expression capabilities (such us the possibility of describing dynamic roles) and by the use of ontologies. Furthermore, since we have indications about CLFPs utility in the development process, we are currently working to deepen in this research line.

And, in general, we plan to continue and perform new long evaluation studies in real contexts that could enhance previous validation of our claims and shed light on these proposals. This long-term effort is consistent with the need for rigorous evaluation studies in the field of Learning Design. Although the IMS-LD specification has been released rather recently, the appearance of appropriate software tools (editors, players, etc.) should trigger deeper evaluation studies in the near future regarding proposals like the ones presented in this paper.

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