Using a Theoretical Framework for the Evaluation of Sequentiability, Reusability and Complexity of Development in CSCL Applications

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Abstract

In this document we describe how the use of an educational telematic framework has helped us to evaluate and improve the properties of sequentiability, reusability and decrease of complexity in the developing of constructivist collaborative learning applications. This framework is represented by three levels, namely: situational, constructivist and co-operative level, which are based on a knowledge-construction spiral model; its representation is completed by means of a series of five templates which describe those properties that must be included in CSCL applications and are designed following object-oriented techniques; subsequent to this, three CSCL applications that deal with three different learning contexts serve as a basis for the introduction of the use of the framework, and finally, we provide an outline of its usefulness in the evaluation of these three CSCL applications regarding the above mentioned properties.

Keywords: theoretical and methodological framework, formative evaluation, sequentiability, reusability, complexity of development

1 Introduction

CSCL (*Computer Supported Collaborative Learning*) is a paradigm emerging from educational practice, learning psychology and Information and Communication Technology (ICT) (Koschmann, 1996; Wasson, 1998); its main characteristic is that the role of technology consists of giving assistance to the human elements of the educational process (teacher and student) in order to enable collaborative learning processes.

Due to this impact, we can observe both a numerical and a typological increase in the sort of applications that solve this problem. To set but a few examples, we can find applications designed in order to learn a wide variety of skills: *scientific* (Suthers, Erdosne, & Weiner, 1997), *social* (Osuna, Díaz, & Dimitriadis, 1999), *cognitive* (Dillenbourg & Self, 1992), *writing* (González et al, 1998) etc. These applications use completely different learning contexts, therefore making it difficult to establish a relationship among them and resulting in isolated applications (Roschelle et al., 1999) which do not enable an observation of the comprehensive development of the students.

The relationship among the applications can be considered from two different points of view: 1) *sequentiability*, dealing with the relationship that must exist among the different learning activities that are performed in the classroom and 2) *reusability*: dealing with the possibility that a CSCL application can be used in different teaching-learning contexts. The former focuses on organising each of the applications in continual learning situations (Glenn, Koschmann, & Conlee, 1995) and the latter on using the same staple application but in different educational levels. This way, the term *reusability* is considered in this paper at a coarse grain of granularity, dealing with the adaptation of applications or modules to different situations. Besides these two desired properties, we encounter serious problems when the teacher tries to incorporate technology into the classroom; teachers are not usually technology-literate and have to resort to experts on technology and application development. These facts increase the *complexity* of the development process (Carroll, 1997) and hinder the possibility of discovering a relationship between CSCL applications.

How can we then aid the teacher in order to enable the task of developing applications and making them sequential and reusable? In our research work, these three requirements have been detected using an ethnographic approach (Goetz and Lecompte, 1988) and have been dealt with through the design and use of a telematic-educational framework. On the one hand, it deals with the constructivist collaborative learning problem and, on the other, with the role of technology in this context.

A framework is defined as *"a generic structure that enables the creation of different applications of the same domain"* (Fayad & Schmidt, 1997). The *generic* characteristic implies that a framework must not be limited for all the specialised applications that will emerge from it. Besides, it can be understood or considered as a "*semi-complete*" structure that can become specialised in order to produce adequate applications (Fayad & Schmidt, 1997; Schmid, 1997). That is, it is plausible that the framework does not include all the elements, but, on the other hand, it allows the possibility of adding any specific aspect of a particular domain; this makes it be considered ever-growing or increasing.

Whether it be generic or semi-complete, we can still appreciate that since the applications have the same origin, they will also share some properties. This characteristic should allow actions carried out by one application to be used in a different one whenever they are similar and the same properties are at stake. By using this type of organisation of properties, we aim at achieving applications that allow for *sequentiability*, *reusability*, and for a decrease in the *complexity* of their development.

The use of frameworks for the development of learning technology has been the main concern for a variety of research groups: frameworks related to constructivist learning aspects (Chen & Zhang, 1999); to the activity centred design (Gifford & Enyedy, 1999); to the configuration of online education (Gibbons, Crawford, Crichton & Fitzgeral, 1999); to the development of multimedia-based cognitive models (Fetherson, 1998); to the process of application development (Gómez, Galvis & Mariño, 1998). There are also some frameworks that focus on the development of practice-oriented activities based on collaborative contexts (LAB, 1999). Some of them have even tried to fuse different educational theories through technology (Farance & Tonkel, 1999). These frameworks cover very important aspects for the development of CSCL applications; however, they focus on very specific aspects, which makes them stronger regarding this particular aspect but weaker in others. This situation has led us to create a new global framework that deals with different aspects derived from the development process like sequentialibity, reusability, activity centred orientation, the need of common language between teacher and developer, etc.

The present document describes the use of a layered-based framework for the development of CSCL applications. First, section two presents the model that serves as a basis for the framework, which is described in section three. Then, we show the use of the framework for the development of three applications in the classroom; together with this, we can see the evaluation of the advantages of reusability and sequencing and of the complexity of development attained through the use of the framework. And finally, we include the conclusions reached after the use of the framework.

2 Constructivist collaborative learning model

Before describing the CSCL applications framework, we will define the domain model to which it will be applied. We focus on modelling collaborative learning taking as a basis *situations* and *knowledge construction* (Sherman, 1995; Wilson, 1997); a detailed explanation will follow.

The model is represented by the spiral in Figure 1; in the inner part of the ring we find the *students* who are the elements on whom the process focuses. Those students interact and make up the *group*. There is another participant in the group, namely the teacher, whose role is that of *mediator* and who carries out those actions needed to take the students closer to the *context*. In order to reach that context properly, the mediator *creates meaningful zones of proximal development* and *cognitive bridges* and presents them to the group *through social interactions.*

The evaluation is present all throughout the knowledge construction process. With each activity, the students develop *new schemes*, which will become *previous knowledge* when they start the following activity or the new situation. this aims at achieving a "psyco-pedagogic link" between the different activities and at the establishment of common factors among learning situations (Osuna & Dimitriadis, 1999).

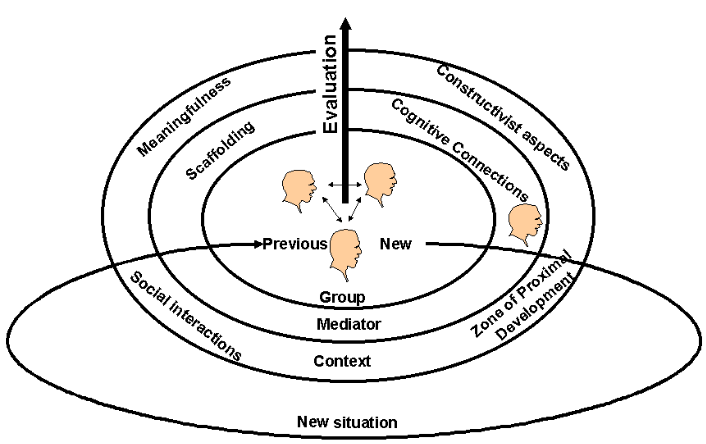

Figure 1. Constructivist Spiral: a model that serves as a basis for the framework

The elements represented by rings are related to each other, though without a pre-established order. That is, the students can *interact* with other students, with the mediator, with several students, among themselves, etc. In an interaction context, we find the possibility of achieving the above-mentioned construction of knowledge; besides, the model provides a context that can be used as a basis for the evaluation of the interactions.

In order to be able to put into practice a model like that, several situations that focused on the constructivist educational process had to be created. A *learning situation* takes into account those cognitive values that are related to the student who cooperates or takes part in such situation. In the case of CSCL applications, those considerations that should establish a context would be of two types: on the one hand, those related to knowledge construction cognitive principles and, on the other, those related to the context in which the situation will take place. Both considerations are numerous and complex and lead us to some added difficulty for the analysis and development of the application. This is why the model proposes dividing a learning situation into several small units which are called *learning activities*; they present finer grain *granularity* than the situation because they seek a unique objective and at the same time they do not forget that the learning situation has a global objective that has to be achieved.

Once the knowledge construction model has been defined, we can built a framework that develops the ideas of the model. The modelling of the constructivist spiral from a layers and objects perspective will be presented now.

3 DELFOS framework

DELFOS is an acronym which stands for *A Description of tele-Educational Layer-Framework Oriented to learning Situations* (Osuna, 2000). The main aim of this framework is to enable the construction of telematic applications for collaborative learning situations with a constructivist orientation. In order to achieve this, the framework defines a *development process*, supported by a set of templates, which include a series of requirements (properties) that must be covered by a CSCL application and an *architecture* based on *layers*, which describe and set the application design. Both elements are described below in this section.

3.1 DELFOS development methodology

DELFOS defines a development process based on the principles of the participatory analysis (Chin, Rosson, & Carroll, 1997) and iterative design approaches, in which a formative evaluation based on interpretative methods plays a central role. In order to support this development process, the framework offers a series of five templates which comprise situations, activities, roles, objects and interactions (Martínez et al., 2000); they are described as follows:

Template 1. Learning Situation. Describes the pedagogical scope and external variables of the collaborative learning process. It is made up of three aspects related to the situation:

Aspects	***Parameters***
General Data	Identifier, Learning Situation.
Pedagogic Characteristics	Description, Objective, Content, Metaphor, Relationships with other Situation, Activities involved, Roles, General Objects, Learning Techniques.
Groups	Group Configuration (*heterogeneous, homogeneous*), Group Variation (*same members, different members*), Group Size (*minute, small, large*).

Template 2. Learning Activities. Describes those activities that make up the learning situation:

Aspects	***Parameters***
General Data	Identifier, Name of the learning activity
Pedagogic Characteristics	Description, Objective, Content, Metaphor (or part of it), Relation with other Activities, Educational Intention (previous knowledge exploration, social interaction, evaluation, reflection, alternative solutions, context exploration, identification of objectives, representation modes, presentation of information), Learning Technique (brainstorming, case studies, concept modeling, free discussion,etc)
Roles and Objects	General Roles, Specific Roles, Autonomous Objects, Objects.
Activeness	Activity type (individual, collaborative), Interaction (synchronous, asynchronous), Floor control (request, free, one at a time, several at the same time)
Group	Group Dimension (several students, several groups, both).
Context	External Communication, Context Shift, Workspace (*individual, shared, both*).
Session	Policy to join the session (all at once, at a specific moment, allow late-comers); Criteria to accept late-comers, (accepted without discussion, decided by mediator, voted); How to leave Session (at will, mediator control, when activity ends).
Register	Participants Registration (mediator control, at will) Registration Moment (beginning, while in progress or end of session)
Time	Activity Time Span (fixed, variable (action execution, role action)). Notification (before, during, end).
Mediator	Teacher (non-participate, participate (watcher, commentator)).
Interactions, Roles and Objects	Interactions, Roles and Objects Name.

Template 3. Roles. Aims to describe those roles that had been mentioned in both the situation and the activities templates. It is divided into three different parts:

Aspects	***Parameters***
General Data	Role Name, Role Objective, Role Origin (*situation, activity*).
Role Properties	Individual represented, preferred physical properties (colour, weight, height, specific characteristics, physical drawbacks, other). Role skills (singing, dancing, writing, other).
Context Elements	Space, Movement, Icon representing it, Action manipulation device, Communication skill (*writing, gesticulation, speaking*).

Template 4. Objects. Describes the elements that compose the space interactions:

Aspects	***Parameters***
General Data	Name, Objective, Origin (*situation, activity*). Representation, Triggers Interactions, Thought
Object Properties	Properties(colour, weight, height, specific characteristics, physical drawbacks, other). Skills (singing, dancing, writing, other).
Context Elements	Space, Movement, Icon representing it, Action manipulation device, Communication skill (*writing, gesticulation, speaking*).
Object Nature	Type (Dependent, Autonomous)
Activity (only autonomous objects)	Representation, Interactions Trigger, Thought (*inherent, derived*)

Template 5. Interactions. Descriptios all possible interactions among roles, between objects and roles and among objects themselves:

Aspects	***Parameters***
General Data	Interaction Name, Description, Roles and Objects in it, Interaction Origin.
Interaction Data	Interaction Content, Interaction Conscience, Interaction Effect, Interaction Time Span.

3.2 DELFOS layered architecture

The properties of the learning situations, obtained with the use of the templates, are represented by means of a layered architecture. Layer III or *situational layer* is the one where human-human interactions are presented, produced and carried out. It represents the space where the student collaborates, constructs and acts in an active way. It includes the configuration of the elements that must be considered in a learning situation. Layer II or *constructivist layer* stores, reproduces and analyses those interactions that have been produced by each of the active elements in the situational layer; besides, it covers the evaluation and scaffolding processes. Finally, layer I or *co-operative layer* aids the students that form the groups by means of the telematic net.

The layers are further described in terms of an object-oriented architecture, which represents the elements and services provided for each layer. The UML (Unified Modelling Language) diagrams representing each layer can be seen in the figures 2, 3, and 4.

3.2.1 Situation layer

This layer designs the *space* where the different roles will interact (Edwards, 1996). The events generated by the actors are represented in this layer. An interface based on the diagram in Figure 2 is used for the design of the space. This diagram is a sketch of the classes that make up the *learning situation*. From a general point of view, this layer must only deal with the problems derived from the creation of the *space* or the *collaboration interface* (Bannon, & Bødker, 1997).

In DELFOS, the interactions that are produced in this layer can be of two types: interactions described in the templates and interactions predefined in the model. The former refer to those interactions the teacher has allowed; for example, *"the student asks the mediator"* or *"the student sends a message"*, etc. The latter represent operations that are well-known in *groupware* applications; among other predefined services we can find *CreateActivity, CreateGroup, EstablishLink, BeginActivity, EndActivity, SendLayerII, Prepare-Interaction,* etc.

3.2.2 Constructivist layer

The set of classes that make up this layer are represented in Figure 3 where we can observe that the constructivist activity has a key role. The events that are carried out are related to the events in the Situation layer; this is done in a way such that once they get to this level, the events are treated and directed to knowledge construction. Some of the services that can be found in this layer are, among others, *Scaffolding, IndividualFolder, ActivityFolder, ReproduceActivity, RelationContents, ConstructivistActivity- Information, ActionsMediator, SignificantInformation, SendLayerIII, SendLayerI.* These services are based on the need for knowledge construction operations (Akhras & Self, 2000).

3.2.3 Cooperative layer

Layer I presents a set of classes that allow modelling the functions for the *transfer of events* required by DELFOS. In order to detect the classes we have taken as a basis the ITU recommendation T.122. "*Multipoint Communication Service for Audiographics and Audiovisual Conferencing Service Definition*" (ITU, 1993). However, its functionality must be supported by operations that allow *asynchronous* tasks. The set of classes that make up this layer are represented in Figure 4 where we can appreciate that the focus is on the idea of having *sessions* among the different members of the group. Some of the well-known services offered by the layer are *CreateSession, JoinSession, LeaveSession, SendLayerII, ExchangeEvents, HistoryEvents, GroupsInformation.*

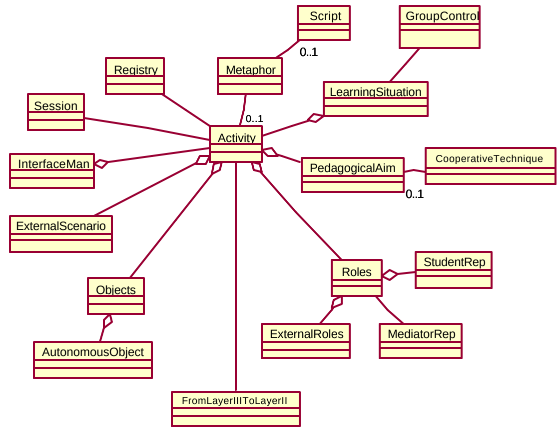

Figure 2. Class diagram for Situational Layer

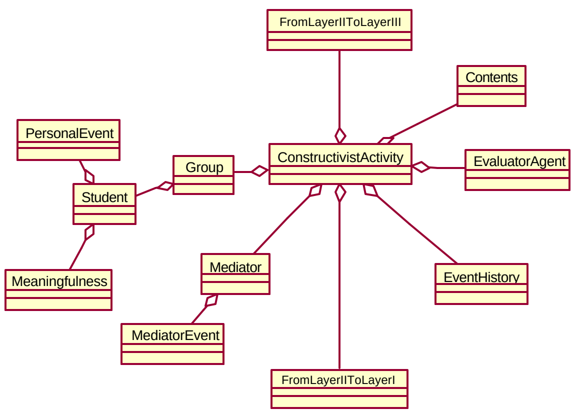

Figure 3. Class diagram for Constructivist Layer

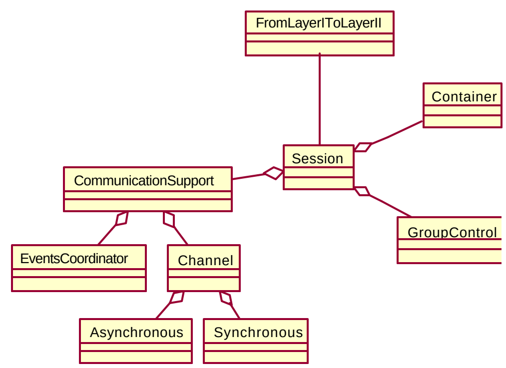

Figure 4. Class diagram for Cooperative Layer

4 Use of DELFOS

The above-described framework has been used with three different groups of teachers, each of them being related to the objectives of an application. In these groups we have experimented analysis and design in three distinct learning situations; these situations have been transformed into CSCL applications and are currently being used in the classroom. Applications are summarised in

Table 1, where it can be observed that each of the situations has a different objective and different activities.

Table 1. Learning Situations used by DELFOS

Situation	***Learning Activities***
PENCACOLAS. (*PEN Computer Aided Composing* cOLlAborative System) (González et at, 1998). **Objective:** it focuses on teaching/learning collaborative writing skills	Individual Brainstorming
	Group Brainstorming
	Individual Planning
	Group Planning
	Composition
	Revision

ATOIDI (Osuna, Díaz, & Dimitriadis, 1999). **Objective:** it focuses on teaching/learning social skills in the labour market.	Interview Appointment Unemployment office Interview Group Discussion Reflection about interview Interview in a company Revision
CECI (CoEdición de Cuentos en Inglés) (Martínez, Escudero, Pajares, Osuna, Dimitriadis, & Anguita, 1999). **Objective:** it focuses on teaching/learning skills for the creation of collaborative didactic materials.	Elaboration Edition Annotation Publication

The three applications have allowed us to evaluate the framework. We will focus now on the three properties that have been described in the introduction: being *sequentiability*, *reusability* and *complexity of development*.

The first stage of the evaluation has focused on the properties of a single learning situation. Hence, *sequentiability* has been evaluated from the point of view of the activities within that situation, trying to detect in them the pedagogic "links" described by the knowledge construction model.

Reusability has been evaluated considering how many modules implementing each activity have been used in another activity.

Finally, the *complexity of development* provided by the framework was evaluated taking into account the groups involved in the development of the applications and usability parameters such as effectiveness, efficiency and satisfaction (Mayhew, 1999). This property was evaluated by studying the three groups of designers. The first one, PENCACOLAS, comprises language and literature teachers and telecommunication engineers. The second one, ATOIDI, comprises social workers, psychologists and telecommunication engineers. And the last group, CECI, comprises pedagogues, teachers, foreign language teachers and telecommunication engineers.

5 Evaluation methodology and results

The evaluation phase in DELFOS is based on an interpretative approach in which qualitative and quantitative data were used. This includes expectation and satisfaction questionnaires, laboratory experiments, interviews, and formal observation (Goetz and Lecompte, 1988). The formal observation process showed the different points of view of the developers and teachers: issues considered as positive results by the former were not very much taken into account by the latter and vice versa. The rest of the techniques aided to attain an integrated view of the evaluation. Table 2 sums up the main results obtained from each of the aspects considered in this paper.

Table 2. Comparative Table of Results

Application	Properties Studied in DELFOS		
	Sequentiability	**Reusability**	**Complexity of development**
Atoidi	High, at the level of the students knowledge and interactions	Activity 1 was used in activity 3	Medium
Pencacolas	High, all the ideas are linked with all the activities	The same component (blackboard) was used across all the activities	Medium
CECI	Low, only comments were monitored	The same interface covered the different aspects of all phases	High

Generally speaking, the properties we were looking for behaved as follows:

Sequentiability has been achieved inside the learning situation; the development of learning activities has made it possible to achieve a "psycho-pedagogic link" among them. For example, in PENCACOLAS, the ideas generated during the brainstorming were subsequently used in the planning activity. In ATOIDI, a sequencing of the interview and discussion activities was achieved; this was due to the use in the second activity of the information provided by the student in the first one. And finally, in CECI we have observed how the comments belonging to each of the versions were continued in subsequent versions.

Reusability has been achieved among the learning situations. The OO approach of the framework and the use of Java programming language for implementation allowed the use of some objects belonging to a particular activity in a different one. In PENCACOLAS, for example, the blackboard was used in all the activities so that the objects that made it up were reused during the different activities. In ATOIDI, the interview activity was reused in a second interview carried out in a different context. The major reusability problem was found in CECI because the context did not really change, the objective of the activity was simply different.

Finally the *decrease of complexity of development* has been achieved in the design of learning activities. Teachers showed a committed and positive attitude towards the use of the framework, mainly because DELFOS templates present the requirements in a language that is familiar to them. And, on the other hand, the representation of the data provided by the templates in a suitable format for their programming is eased by the provision of the UML class diagrams that represent the educational concepts following an OO approach.

6 Conclusions

The use of a framework as the one described in the present document (DELFOS) presents the advantage of combining different aspects of the development of applications; some of these aspects include the design of an activity-centred environment, the aid to the teacher in detecting the requirements using a language that is familiar to him/her, the ease of a pre-designed classroom model for the developer –being this model related to the evaluation requirements and procedures of those framework-derived CSCL applications– etc.; In short, the framework provides both educational and telematic aspects for further consideration and this enables our development of the applications and the teacher's conception of collaborative learning applications.

Furthermore, DELFOS conception in three levels allowed us to reduce the complexity of the problem to smaller worlds, even though the link among them was made more difficult. The framework is supported by the constructivist theory, and therefore, a new knowledge construction spiral-based model was designed; its key aspect was the interaction among students and the aim was that they reached collaborative learning. As for technology, the framework's configuration is based on objects.

On the other hand, DELFOS allowed us to evaluate the variables of sequentiability, reusability and the complexity of the development process in three collaborative learning applications; the result was that the two first ones were reached at a learning situation level and the third one was considerably improved.

Our current work is oriented to the further improvement of all these properties, that may eventually lead to a refinement of the framework itself. Sequentiability has to be studied among learning situations, in order to verify whether DELFOS allows the constructivist "psycho-pedagogic link" at this level. On the other hand, we consider that reusability can be reinforced. Nowadays, it has been improved at a software development level, with the reuse of objects and modules by the programmer. We are considering the component approach in order to develop a set of educational components that implement the concepts defined in DELFOS and can be configured by non-experts. This will help to the decrease of the complexity of the development process.

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