Modeling a Collaborative Answer Negotiation Activity Using IMS-Based Learning Design

Ricardo Valdivia, Miguel Nussbaum, and Sergio F. Ochoa

Abstract—This paper describes the design and impact of a face-to-face Computer Supported Collaborative Learning activity named Collaborative Answer Negotiation Activity (CANA). CANA primarily involves face-to-face interactions among students supported by wirelessly interconnected mobile devices to solve collaboratively a set of multiple-choice questions. The learning outcomes of a CANA applied in two computer science courses are presented. Better results were obtained in a course where reasoning and deduction capacities were important than there were in a technical one where students were required to learn specific knowledge and apply it. A CANA design is described that will permit its reuse in various instructional scenarios. This design is defined as a collaborative learning activity pattern and is specified using IMS Learning Design, an established method of learning scenario description. The application of this method revealed the need to incorporate the notion of Joint Problem Space, a shared knowledge space that supports the collaborative work of the activity.

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R. Valdivia is with the EUI.IIS, Universidad de Tarapacá, Casilla 6 D, Arica, Chile (e-mail: rvaldivi@uta.cl).

M. Nussbaum is with the Departamento Ciencia de la Computación, Escuela de Ingeniería, Pontificia Universidad Católica de Chile, Casilla 306, Santiago, Chile (e-mail: mn@ing.puc.cl).

S.F. Ochoa is with the Departamento de Ciencias de la Computación, Universidad de Chile, Blanco Encalada 2120, Santiago 6511224, Chile (e-mail: sochoa@dcc.uchile.cl).

***Index Terms*—Collaborative learning activity pattern, mobile computer supported collaborative learning, joint problem space.**

I. INTRODUCTION

THE influence of constructivist theory in the field of education has facilitated a vision of the educative process as an eminently social one, in which the phenomenon of learning occurs under the guidance of a teacher through interaction among peers [1]. Teasley and Rochelle [2] refer to collaborative learning as "a process by which individuals negotiate and share meanings relevant to the problem-solving task at hand". If the collaborative learning process is mediated by computers, it is categorized as a Computer Supported Collaborative Learning (CSCL) activity [3].

Typically, collaboration is the outcome of an ongoing concern with building and maintaining shared knowledge related to a given problem [4]. This knowledge is more than just the shared understanding of the problem, for it also embraces the understanding of several aspects of the collaborative work including coordination, strategy communications and monitoring.

Miao *et al.* [5] incorporate the notion of shared knowledge as a source of support for problem-based learning. They also define the concept of shared space, where collaborative group members discuss, identify points of conflict and negotiate which positions will prevail. Collazos et al. [6] highlight the importance of this shared knowledge (or shared space) to support collaborative learning activities. They also propose indicators for estimating the amount of shared knowledge a group possesses (Shared Knowledge Indicator - SKI).

This article presents a face-to-face CSCL process [7] called Collaborative Answer Negotiation Activity (CANA). In this activity, students work collaboratively in small groups on solving a set of multiple-choice questions. Sharing knowledge among students is the central concept in the CANA design. The evaluation process of the activity involved two undergraduate computer science courses. The results showed that CANA boosts student motivation, participation and performance levels [7]. The learning outcomes were found to be better if CANA is applied in courses that make intensive use of reasoning and deductive abilities.

The proposed collaborative activity can be considered as a *learning design component* in that it embeds the application of a pedagogical model for a specific learning objective, a target group and a specific context or knowledge domain [8]. These components describe the teaching-learning process. More specifically, they specify which activities have to be performed by learners and instructors, and under what conditions, in order that students will attain the desired learning objectives [9]. Thus, the reuse or adaptation of these components can be satisfactorily achieved.

In order to ensure that CANA can be reused in, and adapted to, various different instructional scenarios, the activity was specified as a collaborative learning activity pattern [10]. These patterns can be understood as ways of describing types of collaborative learning activities that are easily comprehensible to instructors and software developers. In the formalization of the CANA design, the IMS Learning Design specification [11] was used. This specification is a formal pedagogical IEEE standard promoted by the IMS Global Learning Consortium.

In what follows, Section II introduces CANA, Section III analyzes the utilization of CANA in two computer science courses, Section IV sets out a design process for CANA, and finally, Section V presents the conclusions.

II. Collaborative Answer Negotiation Activity

A. *Sharing Knowledge in CSCL Scenarios*

In CSCL scenarios, collaborative learning is effective to the extent that participants succeed in building and maintaining a shared understanding of the problem they are working on [4]. Soller *et al.* [12] argues that the way a student in a group shares new knowledge with the other group members, and the way the others respond, determine to a large extent how well this new knowledge is assimilated by the group and whether or not they learn the new concept.

CANA uses the notion of Joint Problem Space (JPS) [2] as a way of supporting the creation and maintenance of shared group knowledge. A JPS can be implemented as a shared information structure that supports a problem-solving activity. To build such a structure, the members of a collaborative group must (a) introduce and accept knowledge into the JPS, (b) monitor the on-going activity for evidence of divergences in meaning, and (c) resolve differences that impede the progress of the collaboration. The JPS stores information generated by hidden monitoring processes and provides a real-time awareness of the collaborative process. The JPS not only supports the collaboration process but also facilitates the design of CSCL software applications. Section IV explains how the JPS helps designers specify activity diagrams of intra-group interactions.

B. CANA Description

CANA is a face-to-face CSCL process in which students have to share their knowledge in order to solve a set of multiple-choice questions. Social constructivist approaches highlight the fact that face-to-face pedagogical activities have important advantages over distance ones [13]. The physical presence of others is psychologically stimulating, and the stimulation provided by a group leads to what is known as “social facilitation”. As a result, productivity improves when individuals work on tasks in the presence of others.

In order to facilitate the reuse of CANA in various learning scenarios, the collaborative process was specified as a collaborative learning pattern [10], which involves a structure as well as a dynamic for the instructional process. Both of these aspects need to be considered in the activity design to facilitate replication of the collaborative process.

The CANA structure is represented through the set of activities and involved actors, which are described in Table I. Table I formalizes the CANA structure following the proposed method of Hernandez-Leo *et al.* [14] for specifying a collaborative learning activity. The CANA dynamic is described by a collaboration script consisting of a set of instructions governing how the group members should interact, collaborate and work to solve the assigned task. The script is a story which the students and instructors perform like actors in a play [15]. The script shown in Fig. 1 is an adaptation of process proposed by Valdivia and Nussbaum [16], and may be described as follows:

1) At the beginning of the activity, students are randomly divided into groups of (ideally) three students [4], [17].
2) Each group receives a set of multiple-choice questions that are answered one by one. Each question must be answered correctly before the group moves on to the next one.
3) Each question is studied by the whole group. Typically, this process involves the collective reading of the question, the clarification and incorporation of the knowledge required to answer it, and the elaboration of solution strategies.
4) After the collective analysis, each student prepares an answer to the question and presents it to the group.
5) The group members present their opinions, then discuss and negotiate these contributions before coming to a unanimous agreement on the group's response to each question.
6) Each unanimous response is compared with the expected answer. If they match, the group moves on to the next question and the process is repeated. If the response is wrong, the group must reinitiate the discussion, possibly with the intervention of the instructor.

TABLE I
COLLABORATIVE ANSWER NEGOTIATION ACTIVITY PATTERN

Facet	Activity	
Name	Collaborative Answer Negotiation Activity (CANA)	
Problem	Students must collaboratively find the correct answers to a set of multiple-choice questions.	
Context	Students inside the classroom solve the multiple-choice questions face to face using mobile computing support.	
Solution	Each group member gives the response he/she believes is correct and the reasons for choosing it. The group then discusses these responses and agrees on a shared solution. If this solution matches the correct response, the group moves on to the next question; if not, discussion of the same question continues and a new answer proposal is arrived at.	
Actors	- Instructor - Learners	
Types of Tasks	Learner: 1. Randomly divided into small groups (3 students) 2. Each group receives a set of multiple-choice questions (MCQ) that is answered one by one. *[REPEAT* 3. Group members collaboratively clarify and share knowledge related to the current MCQ. 4. Individual work by each group member to answer the current MCQ. 5. Each group member expresses his/her position on each question, initiating the discussion process. 6. Group members negotiate until they agree on a single response for the MCQ. 7. If the response is correct, the group can move on to the next question. If not, it must re-discuss the question and arrive at a new response. *] (Until there are no more questions).*	Instructor: 1. Monitors how much time each group is taking. 2. Monitors each group's success in obtaining the right answers. 3. Monitors the knowledge of the groups on the different topics. 4. On the basis of the preceding, intervenes to assist groups, or the whole classroom, with particular difficulties.
Types and structure of Information	– Set of multiple-choice questions given to each group one by one as they answer them correctly. – Recording of each group's level of success in answering each question.	
Groups types and structure	Small groups (preferably three students).	

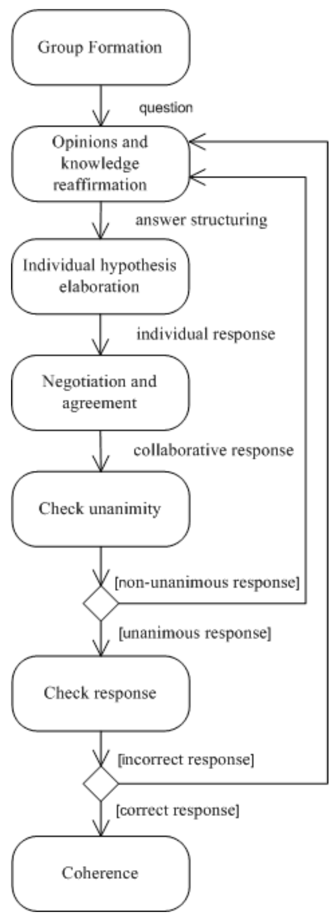

Fig. 1. Activity diagram of a CANA collaboration script

To facilitate the execution of CANA in the classroom, a mobile groupware application was developed that runs on Personal Digital Assistants (PDA) interconnected through a wireless network (Figs. 2 and 3).

Fig. 2. Learning environment of a CANA

The instructor uses a master PDA to monitor the student's activities (Fig. 3), which displays a grid of groups (rows) vs. questions (columns) that the instructor uses to analyze several indicators including:

1) The quality of the collaborative work, indicated by the number of correct answers obtained by each group. This information is color coded, with green (grey in Fig. 3) representing a correct answer, yellow (white in Fig. 3) a single wrong answer and red (dark grey) more than one wrong answer. In the example depicted in Fig. 3, Group 3 is the one with the worst record and which will therefore require the most assistance from the instructor.

2) The level of progress of each group relative to the rest of the class, which is indicated by the advance of the corresponding group row in the grid.

3) The degree of understanding of a given topic by the different groups. The corresponding column indicates how knowledgeable the students are on the subject in question.

Fig. 3. Grid used to monitor the groups' activity

III. Experimentation

Two trials were carried out in two different computer science courses to determine the effectiveness of CANA. These courses were Introduction to Programming (IP), an introductory course with 35 students, and Fundamentals of Programming Languages (FPL), an advanced course with 40 students. The experimental hypothesis was that the periodic use of CANA in these courses improves the students' learning results.

In both cases, performance comparisons were made of experimental and control course sections (Table II). The two sections were given in the same semester (16 weeks, 32 lectures) and were taught by the same instructor. In the experimental section, however, approximately 25% of the traditional expository class time was devoted to CANA activities. Each activity group was made up of three students, with any remaining students forming a group of two or included in a group of four. In the IP course, 17 students participated in the experimental section and 18 in the control section, while in the FPL course, 23 students were placed in the experimental section and 17 in the control section.

Thirteen CANA activities were carried out in FPL and fifteen in IP. In the first CANA session the collaborative methodology was explained to the students, who were asked to follow the sequence described in Table I.

The students' performance was measured on the basis of their midterm and end-of-term exams results. A survey was also taken to determine motivation and social interaction factors. Table II presents the quantitative outcomes, the first six columns, from the left, indicating the course, the exam identification (1: midterm; 2: end-of-term), and, for both the experimental and control sections, the average score (Avg) on a scale of 1 to 7 and the standard deviation (SD).

TABLE II
Quantitative Analysis

Course	Exam	Control		Experimental		Comparison	
		Avg	*SD*	*Avg*	*SD*	*p*	*Cohen's d*
FPL	1	4.5	0.857	5.0	1.048	0.1699	0.52 medium
	2	3.4	1.361	5.1	1.537	0.0015	1.18 very large
IP	1	4.2	1.041	4.5	0.950	0.4445	0.32 small
	2	3.2	1.023	3.3	1.339	0.8462	0.09 negligible

FPL exhibited statistically significant differences in its end-of-term exam (p = 0.00159, with an effect size (Cohen's d) of 1.18 (very large)). The motivational and social ability development survey, taken after each exam, showed an important increase in the experimental group compared to the control group [7]. In contrast, for IP the differences between the two sections were not statistically significant on either of the exams (p= 0.4445 and p= 0.8462, with an effect size (Cohen's d) of 0.32 (small) and 0.009 (negligible)). The motivational and social ability development survey for IP also revealed no major differences between the experimental and the control sections.

Since the experimental hypothesis was confirmed for FPL but not for IP, a second experiment was designed and conducted in the following term. Based on observation of the collaboration process, it was felt that the process in IP was weaker than in FPL. In particular, less shared knowledge was generated in IP. Therefore, the experimental hypothesis of the second experience was that the results of applying CANA are better if the course involves a significant amount of reasoning and deduction. This hypothesis can be validated by analyzing the quality of the collaboration process.

The experiment under the new hypothesis was conducted only in the experimental section of each course and involved 28 students in IP and 15 in FPL. The instructor for both courses was the same person who participated as instructor in the first experimentation process. Given that the groups in both courses were randomly formed, the qualitative analysis was conducted using a group of three students randomly selected at each session. In order to facilitate the careful observation of interaction among its members, this group was filmed during the activity.

To determine the quality of the collaborative process and the formation of the JPS, a combination of qualitative and quantitative methods based on a number of indicators was used [3]. Table III presents the average (Avg) and standard deviation (SD) of the values obtained for each indicator. The values obtained were compared on the basis of their statistical significance and effect size (Cohen's d). The analysis of this data led to the conclusion that the collaborative process was better in the FPL sessions. The evidence for this can be seen in such aspects as the depth of the analysis per question, measured by the time spent on each question, and the greater number of right choices at the first attempt. The longer response times for FPL were due to a larger number of interactions among the members of the groups. This high interaction level is evident in the indicators for information delivery, information requests and conflicts, plus the fact that more questions were asked of the instructor.

TABLE III
ANALYSIS OF COLLABORATIVE PROCESS QUALITY

Indicator	Course				Comparison	
	IP		FPL			
	Avg	***SD***	***Avg***	***SD***	***P***	***Cohen's d***
Average duration of the activity (min)	24.1	7.83	39.2	14.98	0.0043	1.34
Average number of questions per activity	11.7	4.45	8.1	2.66	0.0149	-1.00
Average time spent on each multiple-choice question (min)	2.2	0.82	5.1	1.48	0.0	2.57
Right choice at the first attempt (percent)	64.6%	0.09	77.8%	0.13	0.0060	1.25
Information delivery: *Number of times each student delivers information to the group*	6.8	3.86	42	16.9	0.0	3.01
Information requests: *Number of times each student requests information from the group*	2.8	1.74	17.1	6.68	0.0	3.15
Conflicts: *Number of times members of the group express different opinions*	0.7	1.23	2.5	1.33	0.0008	1.46
Negotiations and Agreements (scored from 1 to 3): *3: the group tends to answer questions collectively* *2: one of the members does not express his opinion* *1: one of the members imposes his opinion*	2.3	0.59	2.4	0.51	0.5753	0.19
Number of times the group requests instructor's intervention	0.1	0.35	5.1	2.99	0.0	2.53
Number of non-requested instructor interventions	0.2	0.56	2.1	2.4	0.0161	1.17

Note in the table that the seven upper indicators show significant differences ($p < 0.05$). Therefore it is possible to conclude that during the collaborative activity, the knowledge-building process occurs in an interaction space that is shared by the members of the group, *i.e.*, the JPS.

The only indicator on which no significant difference was measured was Negotiations and Agreements ($p = 0.5753$). These numbers demonstrate that although the IP groups negotiate and agree on common answers that allow them to carry out and advance through the activity, the answers generation and agreement is poor. Without these components of the collaborative process, groups only tend to agree on the right alternative, minimizing interaction among their members and possible interventions of the instructor.

TABLE IV
MULTIPLE-CHOICE QUESTIONS CLASSIFIED ACCORDING TO BLOOM'S TAXONOMY

Course	Knowledge	Comprehension	Application	Analysis	Total
IP	57 (32.5%)	43 (24.6%)	65 (37.1%)	10 (5.7%)	175
FPL	17 (16.2%)	29 (27.6%)	9 (8.6%)	50 (47.6%)	105

The fifteen CANA sessions in the IP course involved a total of 175 multiple-choice questions. In the thirteen CANA sessions in FPL there were 105 multiple-choice questions. Each of them was classified according to Bloom's Taxonomy [18] as a question of knowledge, comprehension, application or analysis (Table IV).

The number of questions per classification indirectly reveals the nature of the two courses. Whereas IP covers elementary notions and skills in the programming area, FPL is focused on the comprehension and analysis of algorithms and the various implementation strategies of the different programming languages.

When students were given a knowledge question, they only had to agree on the correct concept or definition. With a comprehension question, however, the application of a concept in a new context may imply a need greater discussion within the group. An application question requires problem-solving using the acquired knowledge. In this case groups start by reaffirming their knowledge, applying it and comparing the resulting answers. An analysis question involves studying the information and its components, identifying causes and reasons, identifying models, making inferences, finding underlying structures and identifying relationships [19]. This type of question leads to debate that should improve group interaction.

IV. CANA DESIGN

This section sets out the design of a CANA, its main components and the services required to implement it. A fundamental role in the activity is played by the Joint Problem Space, which is explicitly incorporated in the design in terms of the social interactions that occur in the shared space.

A. Specifying CANA with IMS Learning Design

The IMS Learning Design (IMS-LD) educational modeling language was selected to formalize the design of a CANA. It is claimed that this language can formally describe learning component designs for a wide range of pedagogical approaches [9]. A learning component embeds pedagogical content and an instructional strategy for delivering it. The component can also be considered as a unit enabling the student to attain one or more interrelated learning objectives [11]. In practice it may be a course, a module or a collaborative activity such as the proposed CANA.

Although IMS-LD has been successfully employed in the specification of CSCL activities [20], several limitations have emerged in its ability to represent learning experiences based on groups [14], [21]. The main such shortcoming is its lack of support for representing the shared work environment that is essential to collaborative activities. Several researchers have identified the key design aspects (or components) present in most collaborative applications [22], 23]: shared objects, work sessions, users, roles, floor control and awareness. All of them require a shared infrastructure for storing two types of information: (1) information to be shared among collaborators, and (2) meta-information related to the current collaboration process. The first type is used directly in the collaborative activity itself while the second type is required to provide coordination mechanisms and awareness of a group's work.

Fig. 4 shows a simplified description of the IMS-LD proposed conceptual model for supporting a collaborative learning component such as a CANA. The model incorporates a new element into the IMS-LD specification which is the Joint Problem Space (JPS), referred to above. This component, distinguished from the others in the figure by its grey shading, represents the shared scenario where a collaborative activity can be performed. In such a scenario, each person plays the role of learner or staff member. In these roles they pursue certain outcomes by executing activities in the context of the collaboration scenario (*e.g.*, the JPS). The method in Fig. 4 represents a play modeled as a work of theatre with acts and roles. The JPS also collects, stores and maintains all the shared information in order to support the collaborative activity. The JPS is comprised of the learning objects, the collaboration meta-information and learning services.

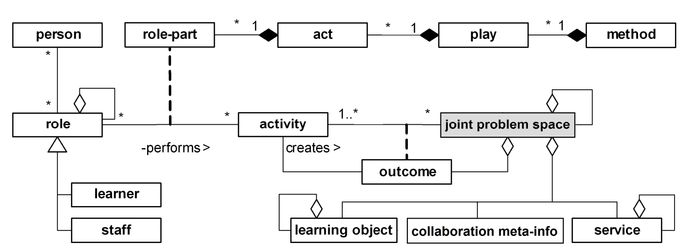

Fig. 4. Simplified conceptual model of the LD

specification

The learning objects represent the resources that will be shared by the team members in their pursuit of a group goal. Examples of such objects are a multiple-choice question, a question response and an argument. The learning services, which make it possible for the actors to collaborate, represent the functionality required to carry out a collaborative activity. An example of this might be the delivery of an answer to the instructor or to teammates. Finally, the collaboration meta-information (related to the current collaboration process) is needed for implementing the rest of the groupware services required in most collaborative applications. This meta-information can be used to implement work sessions that protect the shared resources of the group members from unwanted access triggered by external users. A further use is in generating the metrics that allow the instructor to monitor the students' activities (Fig. 3).

The interaction between an actor and the JPS can be readily specified through a UML activity diagram [24]. The JPS adds clarity and expressiveness to a collaborative learning activity specification when IMS-LD is used.

The creation of an IMS-LD learning component such as CANA typically involves two design stages. In the first stage, UML activity diagrams are used to formally describe the activity narratives or CSCL scripts. UML is a standard modeling language for software products and processes specifications. An activity diagram can be utilized to describe control flows in a collaborative activity. Fig. 5 is an example of such a diagram showing a general description CANA script.

The second stage involves preparing an XML document [25] that constitutes the LD specification. XML has the advantage of allowing semantics to be added to the represented information. Furthermore, since the information is characterized in a standard format, other applications can reuse or adapt the learning component.

B. Design aspects of CANA

UML activity diagrams can describe collaborative activities at two levels: a broad level, where the groups are considered as actors in the proposed activities (Fig. 5), and at a finer level, which focuses on intra-group activities (Fig. 6). In the latter case, certain limitations of activity diagrams for properly describing collaborative learning activities become apparent. In particular, two basic problems arise in the characterization of collaborative interaction [21]. First, the number of participants and their roles is usually variable; and second, the description of the interactions themselves tends to be complex due to the existence of states that, rather than belonging to any one of the participants, emerge from the interaction between them.

The various activities comprising CANA in terms of the roles involved in the collaboration process are depicted in Fig. 5. During the elaboration of the individual responses, each member of the group gets support from the group members' opinions and group knowledge in the elaboration of his/her own personal solution to the multiple-choice question posed. During the group response stage, on the other hand, each member delivers his opinions to the group, initiating the process of discussion, agreement and disagreement that must eventually lead to a unanimous group opinion on the response to the question.

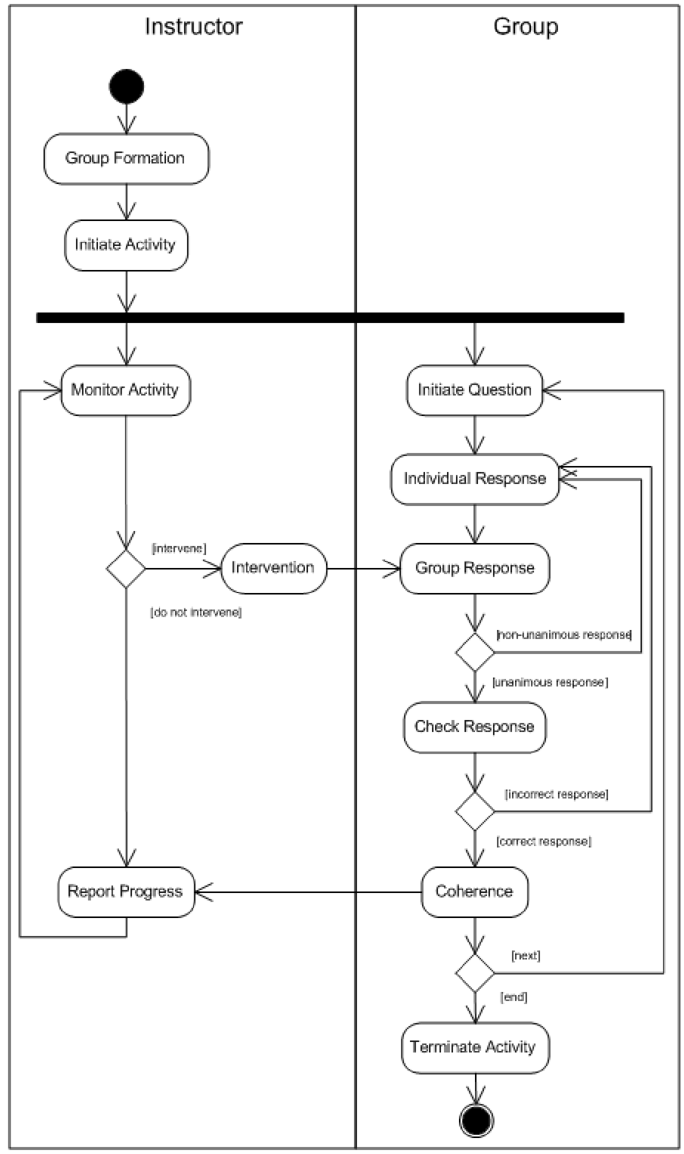

Fig. 5. Group-level activity diagram of CANA

The role of the instructor, by contrast, is to supervise the activity, intervening whenever a group's results make this necessary. In carrying out this function the instructor will have access to a number of online metrics on various aspects of the state of the collaborative process. These metrics are generated by the collaborative application using relevant information collected from the JPS. Such indicators give the instructor an on-line perspective of the JPS being built by each group and thus enable him/her to judge when to intervene and correct any mistaken understanding of a group.

Fig. 6 describes the collaborative activity at the intra-group level. The JPS has an important role at that level and must therefore be specified as an actor in the collaboration process. In the figure an activity diagram column represents an actor or a class, whereas in a learning script it relates to a role and a social organization level. The student (i) column refers to the social role played by each student in group (i=1,…,3). Since each student performs similar activities, these have been generalized into a set of such activities.

The problem of modeling the social interactions between the group members during a CANA was solved via a strategy that differs from the one proposed in [21], which explicitly models each member. Here, an explicit Joint Problem Space was opted for, in which the actions of each member performed "toward the group" are generalized as a single role and modeled as a flow toward the JPS. Each individual opinion will therefore produce a certain degree of conflict at the group level, which affects the development of new response constructions and opinions at the individual level.

The basic architecture of a CANA is presented in Fig. 7. There are two roles in the activity: student and instructor. The groups of students represent collaboration units and the instructor represents the mediator and supervisor of the collaborative process. The learning objects of CANA are a set of multi-choice questions. Finally, the JPS establishes an association between the proposed roles and the learning objects of the activity. The fuller is this work space, the stronger, more efficient and/or more effective will be the collaboration process.

Although the JPS is not formally a part of the proposed IMS-LD, in the authors' view an element representing the JPS concept should be included. The JPS is crucial for monitoring the various aspects of the users' interactions and the results of the collaboration. Using the JPS information the instructors can access both the progress of each group and the level of correct responses to each question. On this basis they can make decisions, during the course of the activity, such as whether or not to intervene, either in particular groups that are performing poorly or at the entire class level, if a problem arises with a given topic. The students can also access this information offline in order to evaluate their own performance in the activity.

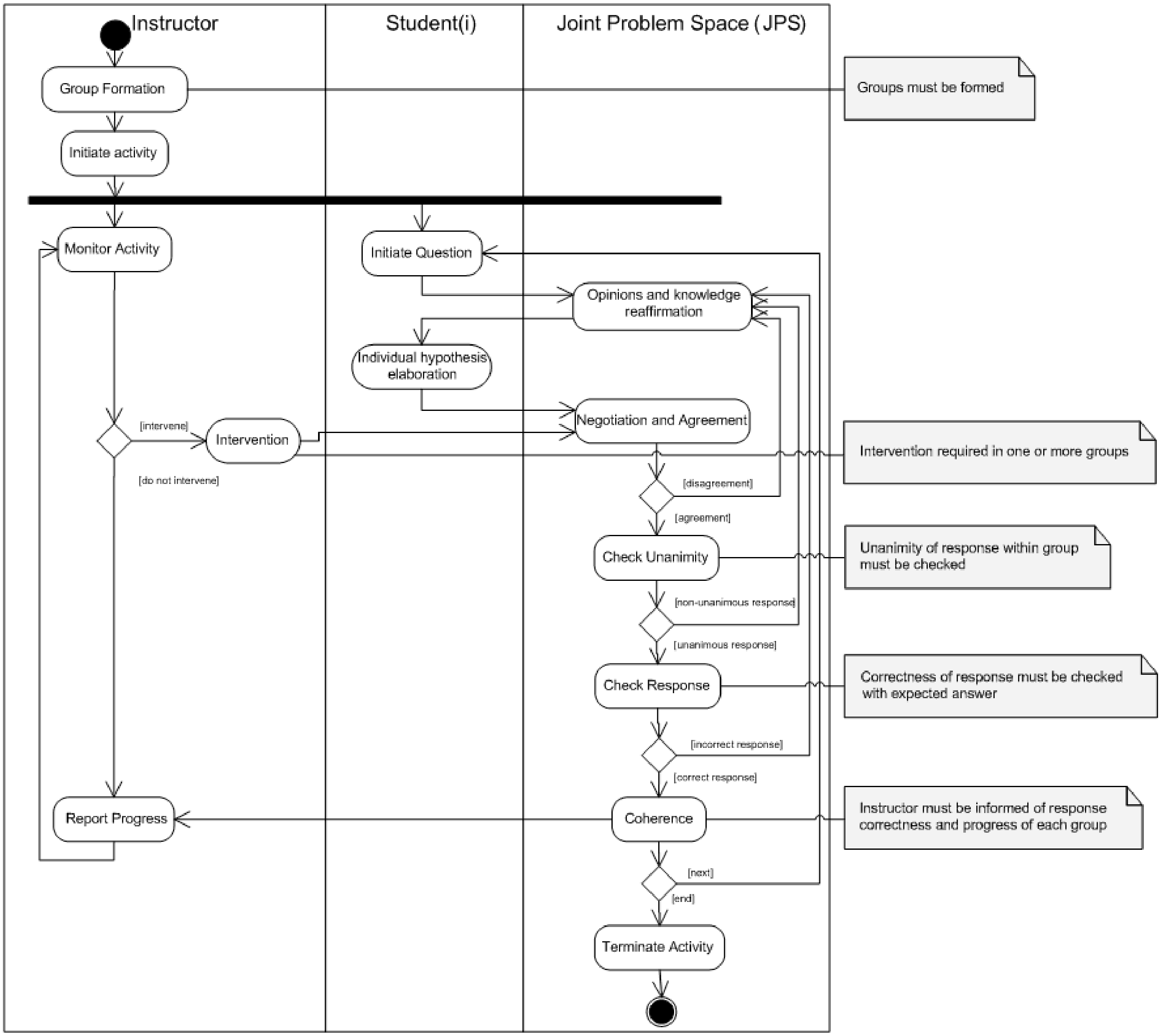

Fig. 6. Individual-level activity diagram of CANA

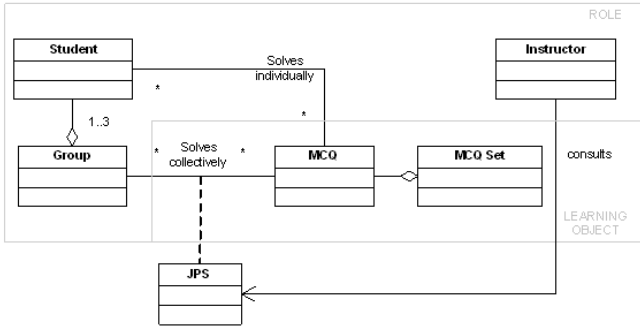

Fig. 7. A CANA class diagram

C. CANA Supporting Services

According to Hernández-Leo [14], the concept of services is central to an IMS-LD. However, the specification of an IMS-LD refers only to certain basic services such as discussion forums, chat rooms, monitoring tools and search facilities. Currently, this specification leaves unaddressed a number of other necessary services that could be specified by learning-scenario designers. To rectify this deficiency Hernández-Leo [14] proposes a special type of service denoted "group service" that is oriented toward the use of CSCL tools for learning design components. Still missing, however, is a description of how this group service tool satisfies the support and coordination requirements of collaborative activities in a learning component.

In CANA design an annotated version of the UML activity diagram is used to determine what CSCL services are required by the proposed activity (Fig. 6). The service requirements thus arise naturally from the activity itself rather than as a later add-on. The process of describing the control flow that occurs during the activity's execution reveals the various points at which technological support is required to perform the following actions:

1) *Creation of Groups*. When launching the activity, the system randomly forms groups of three students and assigns them a set of multiple-choice questions to be solved in class.

2) *Intervention in a group*. The instructor may decide to intervene in a group based on its progress in the collaborative activity.

3) *Checking the unanimity of group responses*. Each time a group constructs a collective response to a question, the system checks whether all group members agree with it.

4) *Checking the correctness of group responses*. The group response to a multiple-choice question is compared with the expected response to determine whether it is correct.

5) *Awareness information for the instructor*. Data on the level of progress (number of questions

answered) and the correctness of the responses (whether the right answer was attained on the first or subsequent attempts) must be reported to the instructor to enable him/her to properly carry out the role of activity facilitator.

The services indicated in points 3, 4 and 5 must be provided over the whole activity so that the entire collaboration process can be coordinated. The service mentioned in point 2 must allow the multiple-choice questions cycle to be interrupted, thus stopping or suspending the class so that the instructor can intervene as required in accordance with the data on the various groups' progress.

V. Conclusions

An experiment conducted by the authors demonstrated that the introduction of a Collaborative Answer Negotiation Activity (CANA) can be an important tool for improving student performance as well as motivating and enhancing their social abilities, especially if the study material involves questions classified in the upper level of Bloom's taxonomy. This type of question is better addressed by a collaborative process such as CANA because of its ability to encourage interactions among group members, generate discussion and motivate instructor intervention. More specifically, this paper revealed the activity's applicability in computer science courses oriented toward comparison and analysis such as data structures, algorithm analysis or logic for computer science, where reasoning and deductive abilities must be developed. In more technical courses such as programming where students learn and apply specific knowledge, its application can lead to unsatisfactory results, however. For this type of content, techniques based on "learning by doing" [26] may be more appropriate.

In the design of the proposed CANA activity, the elements of the IMS Learning Design (IMS-LD) specification can be introduced with varying degrees of specificity from the general to the specific. Thus, the more general levels can serve as a collaborative learning pattern [14] while the more specific ones function as learning components. An important part of the specification is the emphasis placed on the use of UML activity scripts and diagrams, tools inherited from the IMS-LD context, for describing the collaborative activity. With these specification languages, collaboration support and coordination requirements can be identified and then satisfied through the construction of an appropriate technological tool.

The concept of a JPS was also introduced into CANA design in order to improve the clarity and precision of the interaction diagrams. From an implementation point of view, the JPS not only allows the shared knowledge of team members to be stored, but also permits the creation of a temporal record of member interactions. This component thus functions as a sort of logbook of the collaboration process that serves as a data source for further and more rigorous analysis. The JPS also makes it possible to monitor interactions and leads to clearer interpretations of the collaborative results, thus constituting an indispensable element in the description of a collaborative learning environment.

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Ricardo Valdivia is a software engineer and Ph.D. candidate at the Catholic University of Chile, where he is currently working on the use of mobile technology to improve computer science education. He is a professor of computer science at the University of Tarapacá in Chile. His areas of interest include database theory, computational logic and engineering education.

Miguel Nussbaum, Ph.D., is a full professor of Computer Science at the School of Engineering in the Catholic University of Chile, a member of the board of the Chilean National Science Foundation and a member of the “Regional Scientific Committee for Latin America and the Caribbean of the UNESCO Forum on Higher Education, Research and Knowledge.” His research areas are ubiquitous learning and knowledge management.

Sergio F. Ochoa is Assistant Professor of Computer Science at the University of Chile. He received his Ph.D. in Computer Science from the Catholic University of Chile. His research interests include computer-supported collaborative work, educational technology and software engineering. Dr. Ochoa is a member of ACM and the Chilean Computer Society and sits on the Steering Committee of the LACCIR (Latin American and Caribbean Collaborative ITC Research Initiative). He currently serves as an IT consultant for a number of public and private organizations in Chile.