Chapter XII

Communication, Coordination, and Cooperation in Computer-Supported Learning:
The Aulanet Experience

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Abstract

This chapter introduces an approach based on the 3C (communication, coordination, and cooperation) collaboration model to the development and analysis of collaborative systems, by means of a case study of a learningware (AulaNet) and the methodology of a Web-based course, both

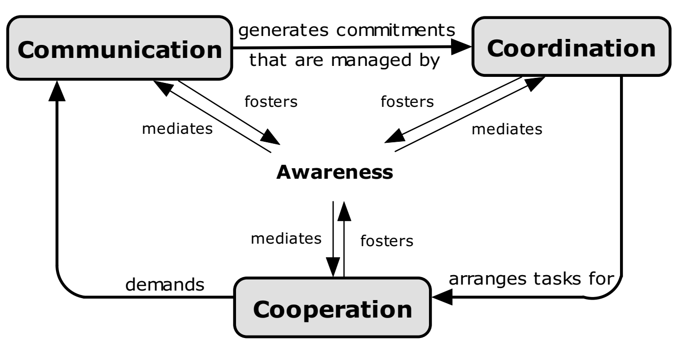
designed based on the model. The 3C model is presented through the analysis of each of its three elements, followed by the case study of its application in the AulaNet environment and in the ITAE (Information Technology Applied to Education) course, an entirely online course that has been taught since 1998.

Introduction

Collaboration may be seen as the combination of communication, coordination, and cooperation. The 3C model was originally proposed by Ellis, Gibbs, and Rein (1991), with some terminology differences. It appears frequently in the literature as a means to classify collaborative systems or as a basis for groupware development methodologies (Borghoff & Schlichter, 2000; Laurillau & Nigay, 2002). In this chapter, we explore the 3C model as a means to represent a learningware application domain and also as a basis for a system development.

The relationship among the 3Cs of the model facilitates the understanding of a groupware application domain. In this chapter, we are focused on the group work domain, which is represented in Figure 1. According to this instantiation of the 3C model, communicating people negotiate and make decisions. The commitments generated during communication are organized into tasks managed by coordination. While coordinating themselves, people deal with conflicts in such a way as to avoid the loss of communication and cooperation efforts. Cooperation is the joint operation of members of the group in a shared space to complete tasks and generate and manipulate cooperation objects. The needs of renegotia-

Figure 1. 3C collaboration model instantiated for group work



tion and making decisions about unexpected situations that appear during cooperation may demand a new round of communication, which will require coordination to reorganize the tasks to be executed during cooperation.

In this chapter, we show how the 3C model has been applied to the development of the AulaNet environment and to the dynamics of a course titled Information Technology Applied to Education (ITAE), currently in its 14^{th} edition. In the next section, AulaNet and the ITAE course are introduced. The following sections detail each aspect of the 3C collaboration model, namely communication, coordination, and cooperation, using AulaNet and the ITAE course as a case study.

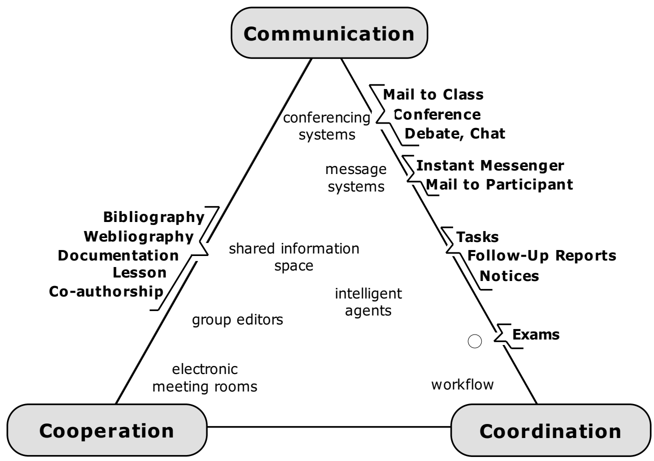
The AulaNet Learning Environment

The manner in which people work has changed with the advent of the connected society. Accustomed to the paradigm of command and control that is taught in the classroom and widely disseminated on the factory floor or, rather, conditioned by it, workers are not up to the new demands of the connected society. They are taught to react to clear orders, well-defined procedures, and specific activities. Their understanding of communication is vertical—memorandums come down from above, and reports are sent up the line. Thus, like in the classroom, horizontal communication—communication with a shift colleague—besides being hardly well thought of is also given no technological support. Knowledge workers, on the other hand, constantly interact with their work colleagues in order to carry out their tasks. The organization that was imposed top-down in the command and control paradigm loses effectiveness and is replaced by one that is peer-to-peer, where communication, coordination, and cooperation predominate.

AulaNet is a freeware Web-based environment for teaching and learning. It has been under development since June 1997 by the Software Engineering Laboratory of the Catholic University of Rio de Janeiro (PUC-Rio). Besides Portuguese, AulaNet is also available for download (http://www.eduweb.com.br) in English and Spanish versions. A comparison with other environments can be found at Zaina (2001).

In its first versions, AulaNet resources were subdivided into administrative, assessment, and didactic services, a common approach in educational tools (Edutools, 2004). Unfortunately, this approach led teachers to use the environment to teach in the traditional vertical way: broadcasting information with a low degree of learner-teacher interaction and no interaction among learners at all. Collaborative learners are expected to have a high degree of interaction among

Figure 2. Classification of AulaNet services based on the 3C Model. The 3C triangle appears in Borghoff and Schlichter (2000).



themselves and with their teachers, who are now supposed to act as coordinators or mediators rather than as information deliverers. Hence, the services were reorganized based on the 3C collaboration model, which is suitable for a collaborative learning approach (Fuks, 2000).

The AulaNet environment's services are currently subdivided into communication, coordination, and cooperation services, as can be seen in Figure 2. The communication services provide tools for forum-style asynchronous text discussion (*Conferences*), chat-style synchronous text discussion (*Chat* and *Debate*), instant message exchange between simultaneously connected learners (*Instant Messenger*), and individual electronic mail with the mediators (*Mail to Participant*) and with the whole class, in a list-server style (*Mail to Class*). Coordination services support the management and the enforcement of group activities. In AulaNet, coordination services include tools for notification (*Notices*), evaluation (*Tasks* and *Exams*), as well as a tool that allows monitoring group participation (*Follow-Up Reports*). Cooperation services in AulaNet include *Lessons* and *Documentation*, a list of course references (*Bibliography* and *Webliography*), and course co-authoring support, both for teachers (*Teacher Co-Authoring*) and for learners (*Learner Co-Authoring*).

In AulaNet courses, teachers can have three different roles, which may or may not be assumed by the same person. The coordinator's role is to design the course, defining and configuring the services that are made available to learners.

Figure 3. The AulaNet interface

The author's role is to produce and insert content. The mediator's role is to animate the group, maintaining order, motivating and evaluating learner participation. In the ITAE course (introduced in the following section) there are two coordinators who also assume the author's role, and there are mediators, who vary from one semester to the next.

The AulaNet services are placed at the disposal of coordinators during the creation and maintenance of a course, enabling them to select those they wish to make available to learners in the menu represented as a remote control unit (Figure 3). During the ITAE course, the teacher gradually makes more AulaNet services available to help the learners understand the environment in which they are studying.

Although Internet offers advantages and facilities for teaching/learning, there are also many difficulties associated with its use. To produce interactive Web-based content, for instance, if an institution does not provide support for it, teachers must comprehend technologies that sometimes are not part of their expertise. To reduce these difficulties they can use environments, like AulaNet, that separate content from navigation. This lets them concentrate on the production of content, using habitual tools such as word processing programs, while leaving the management of learner navigation to the environment. Additionally, integrated communication, coordination, and cooperation services can be added to courses, and some environments supply reports so that teachers can follow up learner participation.

It was with this scenario in mind that the Information Technologies Applied to Education (ITAE) course was designed. The aim of the course is to get students to learn to work in groups with information technology, turning them into Web-based educators.

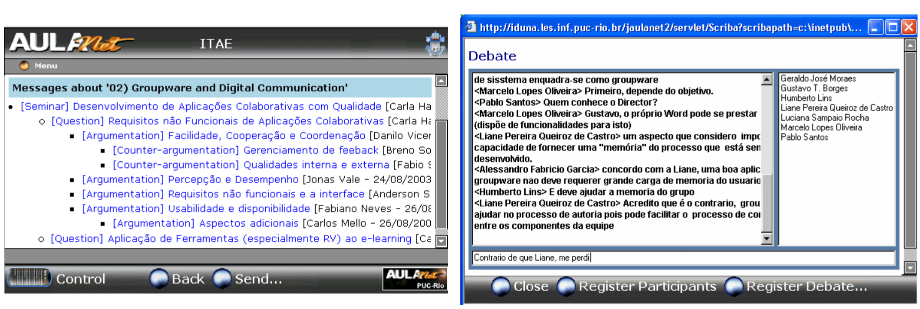
The ITAE Course

The ITAE course has been taught since 1998 as one of the courses of the Computer Science Department at PUC-Rio entirely online, using the AulaNet environment. The course methodology was envisaged to change the behavior of students used to be passive receivers into learners who actively generate knowledge. This process encourages learners to look for their own sources of information, to deal with information overload and to turn information into knowledge collaboratively. Learners are graded for their contributions that add value to the group and not for their individual activities (Fuks, Gerosa, & Lucena, 2002).

In the first part of the course, learners study the contents according to the weekly topic, reading contents in the *Lesson* service, and discussing the topic asynchronously in the *Conference* service and synchronously in the *Debate* service (Figure 4). In the ITAE course, learners conduct the discussions and take turns playing the Conference Leader and Debate Moderator roles throughout the course. All learners are expected to contribute discussing with their colleagues, developing and refining concepts, and having their work observed, commented upon, and evaluated by their peers (Benbunan-Fich & Hiltz, 1999).

In the second part of the course, learners develop an educational multimedia interactive content, working in small groups of two or three, which are formed

Figure 4. Portion of dialogue from the Conference *(left) and* Debate *(right) services*



according to previously submitted profiles plus their performance in the course's learning activities. Based on this information, AulaNet suggests group formations that best satisfy the criteria defined by mediators (degree of skill, interest, and competence) (Cunha, Fuks, & Lucena, 2003). After the initial submission, a period of collaborative peer reviews begins. Members of at least three other groups evaluate each group's content. This evaluation takes place asynchronously in *Conferences* created specifically for this purpose, where learners discuss problems they found in the prototypes. Once this period is over, groups are given a new deadline to present a revised version that incorporates the contributions of their colleagues.

More detail about the course and the AulaNet environment is given in the following sections.

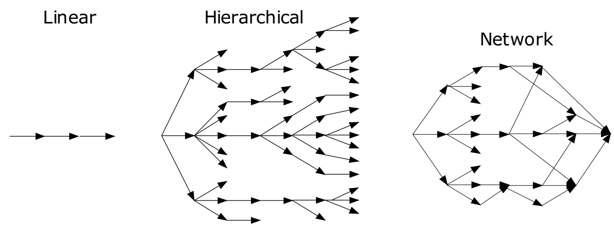
Communication

In the command and control paradigm, communication is considered successful when the sender is informed that the receiver has received the message. On the other hand, the success of communication in the collaboration paradigm entails the understanding of the message by the receiver. The only way of obtaining indications about the receiver's understanding is by observing his/her actions and reactions, since they are guided by commitments assumed during communication. The receiver reads the message and interprets it, changing his/her commitments and knowledge in a certain way. That will prompt him/her to reason about the newly acquired knowledge and react. Thus, sender and receiver move into a discussion where they reason about their actions.

The designer of a communication tool defines the communication elements that will define the communication channel between the interlocutors, taking into consideration the specific usage that it is being planned for the tool (time, space, objective, dynamics, and type of participants) and other factors such as privacy, development and execution restrictions, information overload, and so forth. Then, these elements are mapped onto software components that give support to the specific needs.

Communication elements related to the message characteristics are particularly important in the computer supported learning area. Data and examples collected from several editions of the ITAE course enable us to present an analysis of crucial message characteristics.

Figure 5. Examples of discussion structure



Message Chaining

Communication tools have different ways of structuring messages: linear (list), hierarchical (tree), or network (graph), as can be seen in Figure 5. Despite the fact that a list is a specific case of a tree, and this is a particular type of graph, no one structure is better than another is. Linear structuring is appropriate for communication in which the chronological order of the messages, such as the sending of notices, reports, and news, is important. Hierarchical structuring on a forum, on the other hand, is appropriate when the relationships between messages, such as questions and answers, need to be quickly identified. However, it is relevant to point out that, since there is no way to link messages from two different branches, the tree can only grow wide and, thus, the discussion takes place in diverging lines (Stahl, 2001). Network structuring can be used to seek convergence of the discussion.

In the ITAE course, the forum, based on the AulaNet Conferences service, is used for the in-depth discussion of the course's subject matter. The format of the resulting tree indicates the depth of the discussion and the level of interaction (Gerosa, Pimentel, Fuks, & Lucena, 2005).

The hierarchical structure is also useful to provide indications about the evolution of the class and to identify discussions that moved out from the expected pattern. For example, in the resulting trees presented in Figure 6, it is possible to observe the declining interaction in the 2002.1 edition of the ITAE course. In the first four conferences of this edition, the average level of the tree was 3.0, and the percentage of unanswered messages (leaves) was 51%; in the last four conferences, the average tree level was 2.8, and the number of leaves was 61%. This illustrates that the conversation structure is useful to detect undesired characteristics, such as the low level of the trees and high number of leaves, which, in this case, indicate a low level of interaction among learners.

Figure 6. Conversation structure of some ITAE conferences

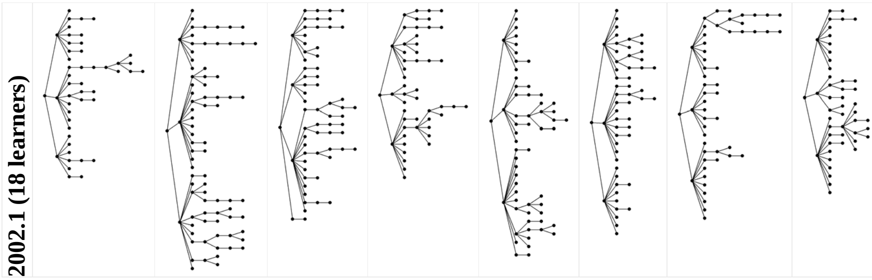
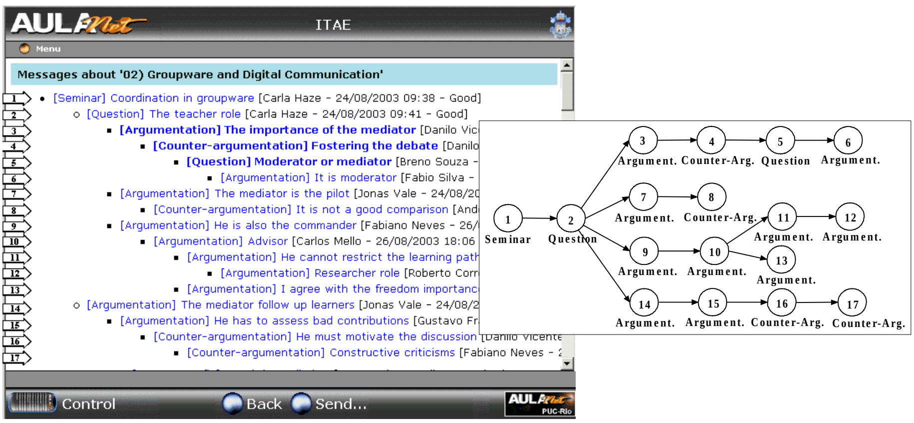


Figure 7. Tree derived from a conference with the message categories.



Message Categorization

Upon preparing a message, the author chooses the category that is most appropriate to the content being developed, providing a semantic aspect to the relationship between messages. Looking at the categories, learners and mediators estimate how the discussion is progressing and the probable content of the messages. AulaNet does not force the adoption of a fixed set of categories. The teacher who plans the course can change the category set to the objectives and characteristics of the group and their tasks.

The categories adopted in the ITAE conferences were originally based on the IBIS' node types (Conklin, 1988). Currently, the categories being used are: Seminar, for the root message of the discussion; Question, Argumentation, Counter-Argumentation, and Clarification. Figure 7 presents a portion of a dialogue from a conference showing numbered messages mapped to a tree.

Categories clearly help to understand the relation between messages without having to inspect their content, thus complementing the information provided by the message structure and helping to identify the direction that the discussion is taking. For example, in a tree or a branch that only contains argumentation messages, there is no confrontation of ideas taking place, while an excessive number of counter-argumentations may indicate that the group has gotten into a deadlock or there may be interpersonal conflicts taking place (Gerosa, Pimentel, Fuks, & Lucena, 2004).

In order to provide proper support for communication, the designer should also take into account coordination and cooperation elements. Coordination elements deal with access policies to the communication channel, while cooperation elements deal with information rendering and registration. These elements are discussed in the following sections.

Coordination

Coordination organizes the group in a way that avoids the loss of communication and cooperation efforts and ensures that the resulting tasks are carried out in the correct order, at the right time, and in compliance with the restrictions and objectives, enforcing the fulfillment of the commitments assumed during communication (Raposo, Magalhães, Ricarte, & Fuks, 2001).

Coordination involves the pre-articulation of the tasks, their management, and post-articulation. Pre-articulation involves actions that are necessary to prepare coordination, usually concluded before cooperation begins, such as the identification of goals, the mapping of these goals into tasks, the selection of participants, and the distribution of tasks among them. The post-articulation stage occurs after the end of the tasks and involves the evaluation and analysis of tasks and the documentation of the collaborative process. The management of the tasks being carried out is the act of managing interdependencies between tasks that are carried out to achieve a goal (Malone & Crowston, 1990).

The great challenge in designing coordination mechanisms in groupware is to achieve flexibility without loosing the regulation, which is necessary in some situations where the social protocol is not enough. Collaborative systems should not be designed based on the assumption that the systems will automate all the articulation work. The system should not impose rigid work or communication patterns, but rather offer the user the possibility to use, alter, or simply ignore them. This way, coordination flexibility and accessibility should be pursued by learningware designers.

Activities' Flow

ITAE's learning activities exemplify a typical situation that requires pre- and post-articulation to define and refine the coordination itself. ITAE has been continuously evolving based on the feedback provided in previous editions. Learning activities that had been planned in advance for an edition were analyzed and afterward reformulated in the light of the results obtained in that edition.

Figure 8 shows the sequence of tasks planned for the ITAE course. After the initial introductions, there are eight topics for content studies, each of them comprising content reading, asynchronous conference, and synchronous debate. Finally, there is the content-generation activity, which is also subdivided into three sub-tasks, and the course finalization, when the final grade is announced.

The overall view of the course workflow indicates that it is necessary to have a hierarchical representation of activities. In Figure 8, for example, the composed activities represented inside the boxes are internally subdivided into more

Figure 8. ITAE flow of activities

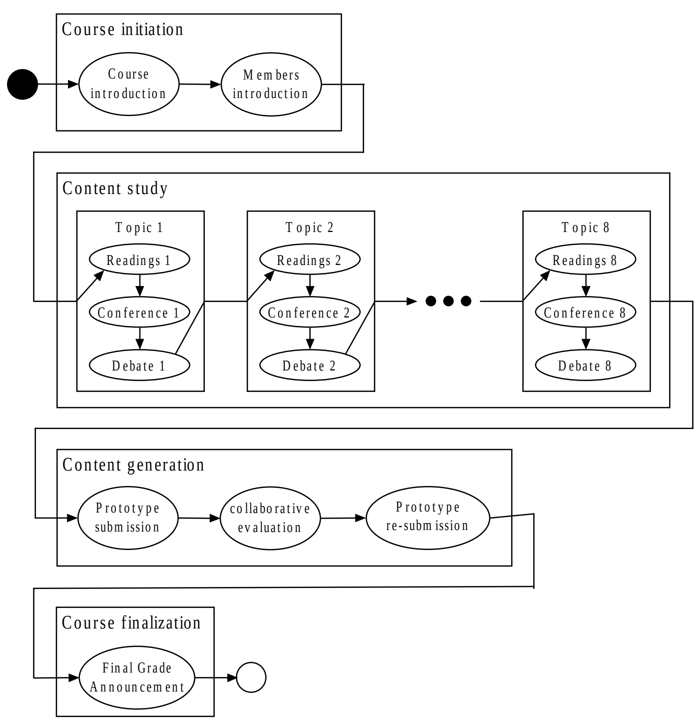
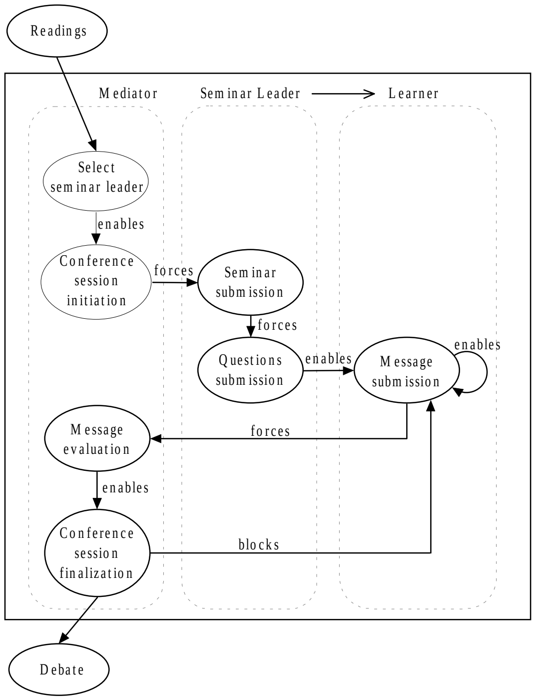


Figure 9. Expanded workflow of a conference



detailed sub-activities. For example, the content generation by the learners has three sub-activities, namely, prototype submission, its evaluation by other groups of learners, and prototype re-submission. Getting into an even lower abstraction level, it is necessary to decompose some activities until atomic ones and detail the kinds of interdependency that exist among these activities. Figure 9 presents the expanded workflow for the weekly conference activity. This activity involves three roles. The mediator (teacher) selects the learner that will play the seminar leader in that week and initializes the seminar session. The leader must then submit the seminar message to the conference and propose a number of questions to be discussed. The discussion takes place by means of message submissions by the learners to the conference. Each of these messages is evaluated by the mediator, who may also finalize the session.

In Figure 9 there are also indications of the kind of interdependency among activities, expressed by *enables*, *forces*, and *blocks* operators (Raposo et al., 2001). An example of *enables* relation takes place between the leader's question submission and the learners' message submission. Learners are not able to submit messages before the leader's questions, but these questions do not oblige each learner to submit messages. Actually, the non-participation of a learner may have a negative impact on his/her degree, but this does not harm the procedural flow of the seminar. Other activities are connected with a stronger relation. For example, the session initialization by the mediator *forces* the leader to submit his/her seminar, followed by the questions; otherwise the seminar would fail. The *blocks* operator is also used, indicating that learners cannot submit messages after the mediator finalizes the seminar session. This does not imply that the mediator will not be able to continue evaluating the remaining questions. The mediator must evaluate all questions; some of them may be evaluated after the seminar finalization.

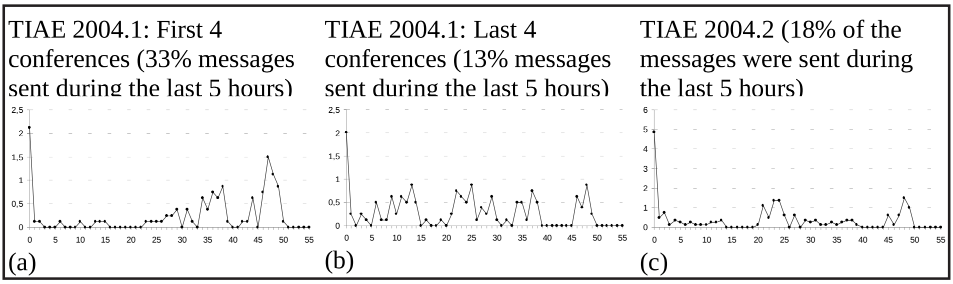
The examples of Figures 8 and 9 show that the teacher should model the course activities, specifying the services, learners, and sub-activities involved. An activity may comprise several sub-activities, different participant roles, and also different services. This is not an easy task, but it is important not only to enable the course coordination, but also to offer a pictorial view of the course dynamics, facilitating its re-design. Once the course is modeled, it will be straightforward to modify its dynamics.

Another important feature that will be obtained with the use of a workflow-based coordination approach within AulaNet is the possibility to create different workflow paths for different learners or groups over a single course. For example, a more advanced class may skip introductory contents, while novices should study them.

Assessment Rules

The ITAE weekly conference is an interesting example showing how coordination can be used to enhance communication. Previous editions of the ITAE course have taught us that most of the content should be self-studied and that most of the discussion should be conducted asynchronously in order to enhance reflection. However, by reducing the time pressure to respond, it is easier for a learner to drop out of the group (Graham, Scarborough, & Goodwin, 1999). Each conference session lasts 50 hours: from 12 noon Monday to 2 pm Wednesday. Until the 2003.2 edition, there was a burst during the last five hours of the conference. In some cases, more than 50% of the messages were sent during this period. This phenomenon of students waiting until the last possible moment to carry out their tasks is well known and has been dubbed “Student Syndrome” (Goldratt, 1997). The act of sending contributions near the deadline disturbs in-depth discussions, for those last-minute messages will neither be graded nor be answered during the discussion.

Figure 10. Average hourly rate of messages in conferences



In order to avoid this unwelcome behavior mediators have to encourage the earlier sending in of contributions. Unfortunately, our experience with this course has shown that this encouragement does not work. In the 2004.1 edition, the following experiment was conducted. The last four conferences had a different assessment rule than the first four conferences, this different assessment being that if until the 25th hour the learners had not sent half of the expected amount of messages, the grade of all the messages sent during the following 25 hours would be divided by two.

Figure 10a shows the 50th hour message bursts, that happened for the four first conferences of 2004.1 TIAE edition. In Figure 10b, representing the last four conferences, the chart does not show the 50th hour message bursts, which indicates that the assessment rule has worked. The percentage of messages sent during the last five hours of conference fell from 33% in the first half of the course to 13% in the second half. Nevertheless, there are lower 25th and 50th hour peaks. However, now mediators and learners have room to access and answer the first batch of messages. The same can be seen in Figure 10c, where all eight conferences of the 2004.2 edition were assessed based on the aforementioned rule. In this edition, an average of 18% of the messages was sent during the last five hours.

Communication and coordination, although crucial, are not enough: “it takes shared space to create shared understandings” (Schrage, 1995). Given that coordination is required to manage the tasks, according to the 3C model it is also necessary to provide a shared workspace where cooperation will take place. In the specific case of ITAE, where knowledge production is the main goal, the example for shared space is the *Conference* service; another choice would be the *Debate* service.

Cooperation

Group members cooperate by producing, manipulating, and organizing information, and building and refining cooperation objects, such as documents, spreadsheets, artwork, and so forth.

In a face-to-face situation, a large part of how we maintain a sense of who is around and what is going on is by being able to see and hear events or actions such as people arriving or leaving, phones ringing, conversations, interjections, and so forth. "These are all things we can potentially use to coordinate our work and play together and we often do so with little conscious effort" (Fitzpatrick, Kaplan, Mansfield, Arnold, & Segall, 2002). On the other hand, in a digital environment, awareness support is less effective since the means for making information available to sensory organs are limited; however, irrelevant information can be filtered in a way that reduces distractions that usually affect face-to-face collaboration.

The designer of a digital environment must identify what awareness information is relevant, how it will be obtained, where awareness elements are needed, and how to display and give individuals control over them. Excessive information can cause overload and disrupt the collaboration flow. To avoid disruption, it is necessary to balance the need to supply information with the care to avoid distracting the attention required to work. The supply of information in an asynchronous, structured, filtered, and summarized form can accomplish this balance (Kraut & Attewell, 1997). The big picture should be supplied, and individuals may select which parts of the information they want to work with, leaving further details to be obtained when required. There must also be some form of privacy protection. The shared space must be conceived in a way that group members could seamlessly move from awareness to work.

Awareness Elements in the AulaNet

Awareness elements are the interface elements through which information designed to provide awareness is made available. These elements should be taken into account when designing groupware. Which awareness elements will be needed, how they should be generated, how to join them up, and how to distribute them must be foreseen. In this section, we will discuss some of these aspects with regard to the AulaNet environment.

The awareness information must provide individuals with a vision of what they will find in each one of the services, to enable them to decide which one to use and to have a notion about the total volume of work that is pending. This information must be summarized in a manner that the participants may quickly obtain a notion about the quantity and the characteristics of the work to do, avoiding information overload.

In AulaNet, whenever a list of topics is presented, as is the case of the class topics in the *Lessons* and the *Conferences*, the quantity of unread items and the total of items of that topic are shown. Other awareness elements include the name and a description of the topic, previously supplied by the teacher, and the name of the content provider who created it. At the end of the list, totals of the quantity of topics, of the items and of the unread or unsolved items are provided.

In order to navigate around the course, participants use a menu of services graphically represented by a remote control unit (Figure 3) that supplies navigational facilities built upon previous selections by the course coordinator. Awareness information can be observed on the remote control unit. In the upper part is the course code, offering an individual awareness element for localization and context. The remote control items make the participant aware of the services available at a given moment. Next to each menu item there is a circular button. This button changes color in order to provide information about the services. A blue button indicates the service that the participant has selected, showing his/her location. A light orange button indicates that possible actions need to be taken. Upon moving the mouse over the button, one sees the number of items upon which some action should be taken (items not read or not solved). A dark orange button indicates a service where no changes have taken place since the last access. This awareness information is designed for individuals and helps them coordinate themselves.

Upon listing the messages of the environment's asynchronous communication services, awareness information is offered in order to help participants contextualize the message, to decide if it is the proper moment to access it or to locate something that is being sought. The category, the subject, the author, the date, and the assessment of each message are shown. Besides this information, the messages that still have not been read are in bold face, indicating that action needs to be taken. In the specific case of *Conference* and *Mail to Class*, where it is possible to explicitly answer the messages, another piece of awareness information that is presented is the nesting of the messages. Through nesting it is possible to identify the connections between the messages, facilitating the understanding of the context. These awareness elements mix individual awareness (things related to the individual work, like the indication of unread messages) with group awareness. The group awareness is related to the cooperation objects, which in this case are the messages exchanged and the discussion threads.

The AulaNet also offers a service called *Follow-Up Reports* (Figure 11) that seeks to enhance the group awareness about its members' activities, providing

Figure 11. Follow-Up Report *interface*

subsidies for coordination. The reports summarize the quantity, extracted automatically by the environment, and the quality of contributions, supplied by the course mediator. Each contribution—messages, participation in debates, submission of content, and resolution of tasks—are marked and, in the majority, commented upon by the teacher.

The reports give an average rating of each participant per service, an average percentage for effective contributions, frequency of participation in the debates, the number of contributions per service, and detailed reports for each service of the course. These reports make it possible for learners to check their performance and compare them with that of colleagues through information that is continuously updated. Furthermore, it helps the participants get to know each other better, to have a notion of how the course is going, of their roles within it, and to choose other colleagues to form work groups. It also lets the mediator organize, motivate, and evaluate the learners and check up on pending tasks.

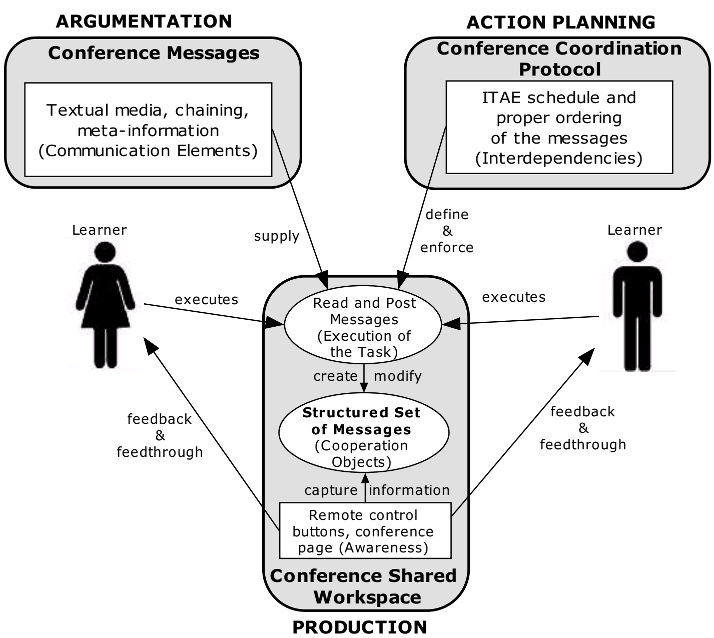
Shared Workspace and Shared Objects

Knowledge and multimedia content are the ultimate production of the ITAE course. Given that the latter is created off-line and outside AulaNet, we are focusing on the former, which takes place in the *Conference* service. It is worth pointing out that AulaNet does not contemplate content authoring. Learners develop educational content using their habitual tools, and the environment supports navigation around the course's shared space.

The *Conference* service provides a shared workspace where learners cooperate by producing and refining knowledge by means of an argumentation process. In ITAE the conference session lasts 50 hours. Learners generate new cooperation objects, in this case conference messages. Learners also construct and handle conference messages (the cooperation objects) and receive feedback from their actions and feedthrough for their colleagues' actions by means of awareness information. In the conference shared space, awareness information about the cooperation objects is displayed, including their authorship, date, category, subject, and the assessment made by course mediators. The 3Cs for the conferences are shown in Figure 12.

The register of group interactions is filed, catalogued, categorized, and structured within cooperation objects. This is how group memory is saved in AulaNet. Ideas, facts, questions, points of view, conversations, discussions, decisions, and so forth are retrievable, providing a history of the collaboration and the context in which learning took place (Kanselaar, Erkens, Andriessen, Prangsma, Veerman, & Jaspers, 2003).

Figure 12. Production in the Conference *shared workspace*

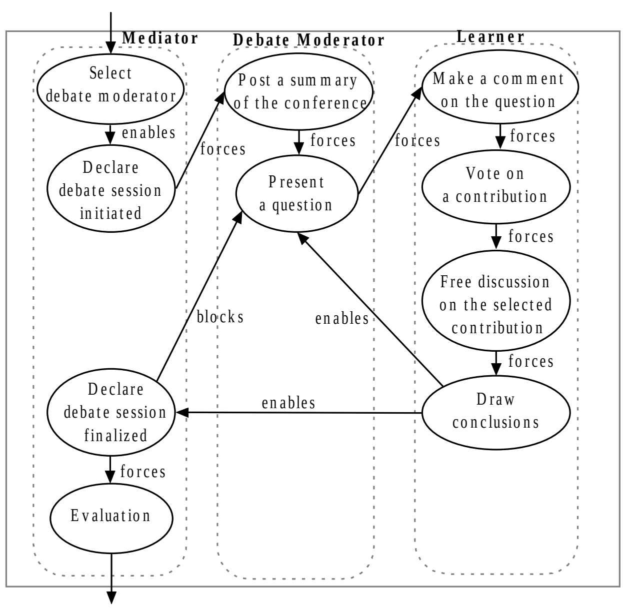


Integrating the 3Cs: The Debate Service Case Study

In the initial versions of AulaNet, the *Debate* service was a plain chat tool, holding an expression element, where learners could type their messages, and awareness elements, where learners participating at the chat session were presented (Figure 4). This version of the Debate was implemented using a communication component, which implements synchronous communication protocols, and a cooperation component, which implements the shared space. This version gives no computer support to coordination, leaving it to the standing social protocol. However, this is not always the case, because some courses use a well-defined procedure to the debate activity, like the one shown in Figure 13, which represents the procedure adopted in a course.

In this procedure, for each debate, the course mediator selects a learner to be the session moderator. It is also up to the mediator to declare the session initiated and finalized and to evaluate learners' participation. The debate moderator posts a summary of the discussion that took place during the week's conference and then poses three questions. For each question, each learner posts a comment, and

Figure 13. Flow of activities in a debate



after every learner has posted its comment, they vote and decide which one will be discussed. Then, a free discussion takes place. Before the moderator poses a new question, learners have to draw their conclusions.

In order to better support tightly integrated activities, like the one exemplified above, in the following version of the *Debate* service (presented in Figure 14), coordination mechanisms were implemented. Floor control, participation order, and shared space blocking ability were added to the service. The shared space was also enhanced by new awareness elements, like session title, message timestamp, and the identification of mediators.

In this new *Debate* version, the same communication component was used, as the synchronous communication protocols and the characteristics of the messages did not change. The cooperation component, which implements the shared space, however, was enhanced by the new awareness elements mentioned above. The main difference, however, is the insertion of a coordination component, which implements the floor control coordination mechanisms.

This example illustrates the benefits of having an architecture that deals with the three Cs of the collaboration model, namely, communication, coordination, and cooperation.

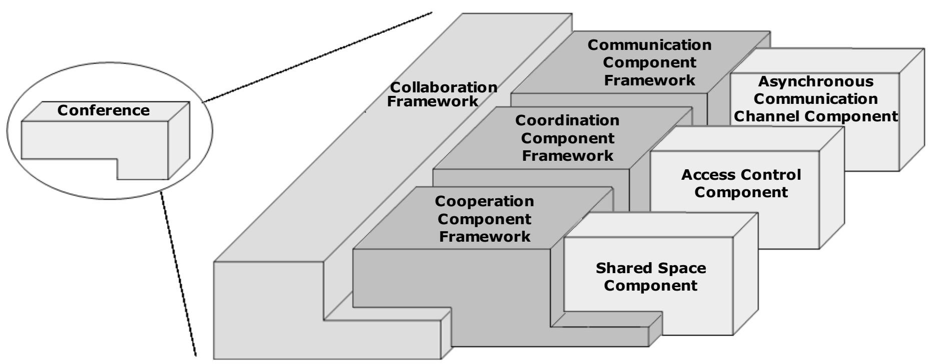
Conclusion

The 3C collaboration model defines three types of services that a learningware may support. The concepts and representation models described in this chapter can be used to guide the functional specification and to provide a common language for representing and describing the collaboration aspects of a workgroup. The application of the 3C model was illustrated throughout this chapter using the AulaNet learning environment and the ITAE course.

The groupware component-system architecture used in the AulaNet environment mirrors the 3C model. Communication, coordination, and cooperation functionalities were directly mapped into the implementation of AulaNet's collaboration services. AulaNet services are being developed using a component-framework-based architecture, as can be seen in Figure 15. There is a common structure implemented by the collaboration framework, which defines the skeleton of the services, and plugged to this framework there are the communication, the coordination, and the cooperation component frameworks, which support each C of the model. Class frameworks are used to implement components, which are plugged to the corresponding C-framework and implement the specific functionalities of the service (Fuks, Raposo, Gerosa, & Lucena, 2005).

Figure 14. Debate service mediator interface

Figure 15. Architecture of a collaboration service in AulaNet



The application of the 3C model was also illustrated through the ITAE course, whose objective is to train learners to become workers capable of operating in a knowledge society. In the ITAE, the learners are encouraged to work in groups, to seek updated information, to argue, to take on and accomplish commitments—at the end of the day, to communicate, coordinate, and cooperate.

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