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Managing Telecollaboration among Engineering Students and Faculty: A Case Study from Two Spanish Universities*

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In today's globalized world, it seems important that students can telecollaborate in a team by making effective use of information and communication technologies. This collaboration format can positively influence their academic performance, enhance engineering student interest in the subject, and improve skills such as communication and teamwork. In this work a collaboration model between engineering students, and also between instructors, from two distant traditional universities is presented and analyzed. Potentialities, challenges and key elements for a viable experience are identified, that would be capable of achieving the proposed objectives, and sustainable over time. Considering these activities as projects, instructors are actively involved in the initiation, planning, monitoring and controlling, and closing of these activities. On the other hand, students are those who must perform scheduled tasks. This article identifies the difficulties and potentials for each of these roles.

Keywords: cooperative/collaborative projects; traditional universities; information and communications technology tools; telecollaboration, engineering education

1. Introduction

In the context of higher education, it is widely agreed that engineering students should develop teamwork skills. The development of teamwork competencies, cultural awareness, or professional communication are also well established objectives described in the ABET accreditation criteria (see www.ABET.org), as well as in the ACM/IEEE Computer Science Curriculum 2013 (www.computer.org). In addition, due to globalization, new challenges arise, as graduates need to be able to work comfortably in an increasingly distributed, multicultural and multidisciplinary team context [1]. It is therefore important that students can work as a team making effective use of Information and Communication Technologies (ICT) tools [2].

Team collaboration competence with ICT tools, or telecollaboration [3], is usually developed in the context of distance learning. This type of collaboration includes interaction among students in distant locations through online communication technologies; and it is guided by teachers or trained facilitators [4]. In this type of learning environment, students are organized in teams that discuss, collaborate, or even maintain social relationships usually making use of universities' virtual campuses (see, for instance, [5] or [6]). However, requiring something similar to students from traditional universities seems rather artificial, since students can easily maintain regular and fluid contact with their teammates given their physical presence at common university spaces.

This reality of traditional universities has motivated the issue of how to find a more natural role for ICT-mediated collaboration. A way to tackle this problem is that students from two distant universities work together. These students would perform, in a joint and coordinated manner, a set of selected activities associated with the development of their studies. The goal is to achieve a better assimilated knowledge (learning, quality of work results, etc.) through cooperation with people who are undertaking similar, but yet, different training. As a result of this experience, we hoped that this kind of collaboration would positively influence academic performance, enhance interest in the subjects, and improve professional and generic skills such as teamwork and communication, which would become increasingly agile and effective and that will be essential for their future careers [1, 7–11].

Ideally, telecollaboration projects should be integrated into the curriculum rather than relegated to extra-curricular activities [2]. Furthermore, those activities ought to be impossible to complete without the assistance of technology; and, therefore, these activities strengthen the active, creative, integrative, and evaluative side of students. A good example can be found in [11] wherein Japanese and UK students made a telecollaboration in a virtual space. Bringing individuals together who have very different pedagogical experiences consti-

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tute a valuable way of creating discussion and facilitating new thinking. The main purpose of these projects is not learning on or with computers, but learning through the use of computers [12]. Another good example is the development of capstone projects by teams of students whose members are spread across various distant universities [13].

In the context of the teaching and learning of a foreign language telecollaboration has been widely employed and researched in the university; but this concept and its modus operandi are often unfamiliar to university educators in disciplines outside the humanities [4]. Hence, an effort to establish such guidelines in technological disciplines can avoid that gap found in the literature. This is the main purpose of this paper.

Over the course of several years, some collaborative activities between students from two distant traditional universities (UR and EHU/UPV) have been organized in the field of computer science. In the first project [14], pairs of students, one from each university and without knowing each other, collaborated on the design of a database. The subjects involved in such experience from the two universities covered different and complementary concepts, producing heterogeneous teams. This circumstance (of having different skill sets) is common among students from different universities, and is actually desirable for team collaboration, especially when the skills complement each other [7, 11]. In that experience [14], the telecollaborating students obtained better academic results than the face-to-face teams; however, they also expressed a lower level of satisfaction. More recently, some experiments with peer review and integration of materials have been conducted [15–17]. Students from universities UR and EHU/UPV published on the Internet the product of a micro-project developed in a particular subject. Classmates and students from the other university offered their assessment and some feedback. In this case, the communication and coordination were carried out via the instructors, reducing in this way the difficulties. However, from the point of view of the lecturers, the tasks of organization and coordination were very similar.

Reflections on those experiences led to the proposal of a model for telecollaboration that maintains the positive influence on learning, while aspiring to improve satisfaction results.
In particular, a model for telecollaboration between students and instructors from two different universities is presented and analyzed. Potentials, difficulties and key elements are identified to promote an experience that is feasible, effective regarding the intended objectives, and sustainable over time, surpassing the fleeting enthusiasms of participating instructors.

The rest of this paper is organized as follows. First of all, we provide a section that reviews some related research. Subsequently, we take into account that a telecollaborative experience can be understood as the development of a project, and devote one section to each of the five types of processes that are identified in a project by the PMBOK® guide [18] (see Fig. 1). First of all, we present the initiation processes that serve to define the telecollaborative project. Secondly, we introduce the planning processes, where the project scope, the task plan, and the set of deliverables to be produced are established. Thirdly, we present the execution processes, that is, we introduce how the tasks (defined in the planning processes) are performed. These processes comprise all the work to be completed by students. Subsequently, we explain the processes of monitoring and control, that are responsible for identifying problems arising during the tasks and provides appropriate modifications to fix them. Finally, we present the closing of the experience processes where the completion of all the activities is verified. The last three sections of the paper reflect on technological changes and technology selection, discuss the desired role for university institutions in these activities, and offer some conclusions respectively.

2. Related research

Table 1 summarizes a set of experiences or studies of telecollaboration. We include information about whether it was a national or international telecollaboration experience, the type of research (qualitative or quantitative), and the type of the studies wherein the experience was conducted. In addition, for each experience we indicate in Table 1 if the student teams consisted of one student from each university (1 to 1), or multiple students from each university (n to n). Moreover, the table also notes the type of activity performed by the teams, and the ICT tools that were employed. Finally, the table also includes whether students or teachers held meetings. The model for collaboration presented herein is the one that is currently used to organize

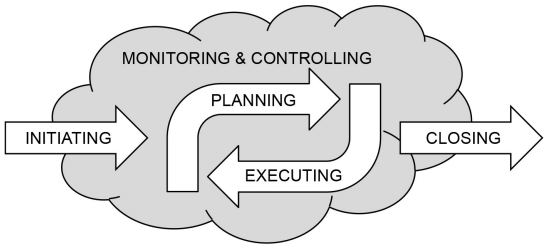

Fig. 1. Group process for project management according to PMBOK® (PMI 2017).

Table 1. Educational telecollaborative studies

	Context	Research	Studies	Teams	Activity	Tools	Students meetings	Instructors meetings
Chidanandan et al. 2010 [21]	International (USA-Turkey)	Qualitative	Computer science	n to n	Project development	Skype, Moodle, email, SVN repositories, Google Docs	Yes	Not described
Díaz et al. 2011 [19]	International (USA-Spain)	Quantitative	Computer Engineering	n to n	Project development	Web-based application	No	No
Domínguez et al. 2016 [15]	National (Spain)	Experimental	Computer science	n to n	Project development	Email, Google tools	No	Yes
Esparragoza et al. 2015 [2]	International (Chile-Colombia-Ecuador-Honduras-USA-Italy)	Quantitative	Engineering	n to n	Project development	Email, audio-video conference, Google tools, social networks	No	Not described
Hilburn and Maguth 2012 [24]	National (USA)	Qualitative, case study	Social studies	1 to 2	Micro-teaching Peer review	Email, Internet radio, podcasting (Talkshoe)	No	No
Jaime et al. 2013 [14]	National (Spain)	Experimental	Computer science	1 to 1	Project development	Email, Moodle, social networks	No	Yes
Laxer et al. 2009 [7]	International (USA-Sweden)	Qualitative	IT-Software Engineeering	n to n	Project development	Email, Skype, Google Docs, Angel LMS	Yes	Yes
Lindner 2016 [10]	Intenational (Germany- Czech Republic)	Qualitative	Business and Economics	n to n	Virtual project teams	Wikispaces wiki, video conference	No	No
Malinowski and Kramsch 2014 [23]	International (USA-French)	Qualitative	Teacher - Foreign language	1 to 2 2 to 2	Partnership French student teacher and foreign language student	Video-conference Skype	No	No
Rohleder et al. 2009 [22]	National (South Africa)	Quantitative	Social work-psychology	n to n	Practical module	Open source LMS	Yes	Yes
Vallance, Martin, and Naamani 2015 [11]	International (Japan-UK)	Quantitative	Media architecture-Science studies	n to n	Programing robots in virtual space	Robot-mediated interaction, virtual space	No	No
Ware and O'Dowd 2008 [26]	International (USA-Spain)	Experimental	Foreign language	n to n, 1 to 1	Peer feedback	Moodle	No	No

this type of practice by us. This model is intended to aid in the organization of experiences in different contexts, and it may serve as a guide to deal with the frequently occurring issues, along with some ideas to solve or even avoid them.

Some studies that deal with telecollaboration between different traditional universities in engineering degrees are included in the literature. Some of them observed the positive effect of telecollaboration, as opposed to face-to-face collaboration, on the quality of the results [14, 19]. Additionally, some of those experiences resulted in high levels of satisfaction [2, 19] whereas others encountered low levels of satisfaction [14].

Some studies in other areas include experiences of international telecollaboration [7, 11, 20–24]. Although the researchers from those studies did not include comparative research, they clearly observed high student satisfaction with their achievements and with the learning process. Other international university telecollaborations are set in the context of language study, aiming for a practical exchange of culture and language (see, for instance, [25, 26], or [23]).

There is another type of research that compares online and face-to-face collaboration, but with a substantial difference: all students are from a single university, and all of them are following the same course (see, for instance, [27] or [28]). In that case, the involved students know each other, maintain physical contact in other subjects, and the cultural diversity is low [19]. The results obtained in those

studies are not conclusive, as some observed a positive effect from the on-line collaboration, as opposed to face-to-face [27], whereas others found a negative or null influence [28].

Other studies propose models or guidelines for conducting telecollaborative activities. Redmond and Lock [8] proposed a conceptual framework model for telecollaboration. This model has three key elements: social presence, cognitive presence, and teaching presence. At the center of those elements is the educational experience. O'Dowd [29] pointed out some difficulties that arise during the completion of telecollaborations in the context of language studies. The most important factor was the time it takes to organize and manage activities. He also highlighted the problems caused by some institutional requirements, especially the integration and evaluation of these activities in the course. Other difficulties were due to lack of experience or adequate guides to conduct the task, and because the instructors were not familiar with the appropriate technologies. Finally, he mentions the difficulty of finding suitable teachers to organize an activity of this type. Chidanandan et al. [21] also provided a set of lessons learned. Cajander et al. [30] included observations of differences in two international collaborations using projects with real clients and open-ended problems where the telecollaboration between universities is based on informal grounds.

Figure 2 shows the main actors in telecollaboration. Face-to-face communication is established within the institution, and the inter-institutional telecollaboration using online tools. Telecollaboration is developed within a generic framework. Usually, face-to-face meetings are held between instructors, but not between students. According to [8], the challenge is to design a framework to guide participants in the use of the appropriate technology that will serve as an effective support tool for collaboration and knowledge construction.

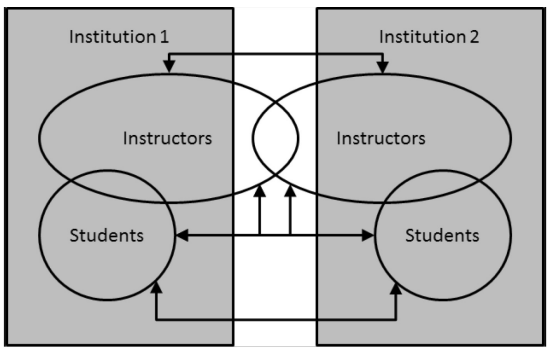

Fig. 2. Remote communication (arrows) and face-to-face (intersections) between stakeholders in our telecollaborative experience.

3. Telecollaborative experience as a project

Since we understand the organization of a telecollaborative experience as the development of a project, we have structured the experience through the five processes typically identified in such a development (see Fig. 1): initiating, planning, executing, monitoring and controlling, and closing processes.

3.1 Framework for initiation

In this section, we discuss the main aspects to initialize a framework for a telecollaborative experience between students of two subjects from two distant traditional universities. The organization of an educational collaboration with other university requires reflection on the appropriate framework for the project. This includes the characteristics of the instructors involved, the academical context, the teaching methods, the subjects involved and, of course, which ICT tools are expected to be employed [3, 29, 31].

3.1.1 The instructors

A starting point for these experiences is a strong relationship between the instructors involved; and a shared vision of the most relevant aspects regarding organization and teaching objectives. Hence, the collaboration among instructors of both universities encourages creativity, the identification of new educational possibilities, and it can also generate synergies [32]. These benefits constitute an added value for their teaching task and a stimulus to further explore this line of work. Personal relationships serve as an important motivation for beginning a partnership between universities [29, 31, 33]. However, there could be situations where an instructor does not know another instructor to collaborate in a given subject. A way to solve this problem consists in using a web platform designed precisely to establish these relationships [25].

An essential starting point is that instructors who intend to collaborate have compatible work cultures, similar objectives, and the ability to adapt their programs [8, 29]. This means that, for example, the quality of the work carried out, the strictness regarding compliance with deadlines, or the rigor with which they handle the concepts of their subjects is of a similar level. When working cultures are similar, it is easier for students to recognize compatible perspectives regarding the work to be performed. In practical terms, the teaching task requires that collaboration among participating instructors is based on mutual understanding and the fluidity of the prior relationship. Under these conditions, it will be easier for the instructors to

both understand and make decisions about problems that may eventually arise.

Instructors who are willing to collaborate may already have considerable experience teaching the subject that will be part of the project. That is, they have definitely acquired a very strong grasp of the contents, the problems that typically arise to the students, and the results obtained with different teaching approaches used so far. The above, however, are not prerequisites for organizing a telecollaboration experience. In this case, some adjustments may be necessary to make the subjects compatible. These adjustments may affect the objectives, content, or cooperative techniques (peer review, meetings, etc.).

3.1.2 The academic context and teaching methods

The first constraint to organize collaboration between students from two universities is academic compatibility [24]. Usually, the two subjects involved should have some common or complementary competences. This does not mean that it is an objective to have courses as similar as possible, but rather that the collaborators need to be aware of the differences and have strategies for dealing with them. The challenge is to turn the differences into advantages, or at least into something that does not jeopardize the collaboration [30]. The subjects must also be taught following compatible calendars [3, 7, 21] and organizational models (for example, both subjects follow a scheme of project-based learning, use jigsaws, or use lectures and exercise classes, etc.). Furthermore, the two selected subjects should also be taught during the same semester. Normally, there are small differences between the semester start dates at the different institutions, or between the end dates. Such differences limit the available period for telecollaborative activities [20]. Additionally, the schedules of students should have enough common time bands without classes, during which they can communicate and collaborate [24]. Some university resources, such as virtual classrooms, should be flexible in order to incorporate students and teachers from the other university [7]. Furthermore, university regulations regarding evaluation must not introduce requirements that impact the organization of these activities.

In addition, the scope of each subject, the starting level of the students, the work plan followed until that time, as well as the level required of students must be analyzed [3]. Also, it is necessary to consider the teaching methodology to be followed, the importance of continuous assessment, teamwork and other activities aimed to develop generic skills. This type of approach strongly contributes to the success of collaboration, and in some cases will even constitute a requirement [7, 21].

The primary problem to initialize this kind of experience is the identification of an appropriate project where students from both subjects can collaborate, and allows them to learn skills for their own subject [3]. At the same time, the students' cooperation during the project ought to be worthwhile for them [8]. Thus, working methods must be selected, and appropriate deadlines for the structure of the classes must be set [3]. Teachers may feel some anxiety associated with the loss of control over methods used in the past which can be attenuated with the reflections mentioned herein.

3.1.3 ICT tools

Another aspect to consider is how to conduct remote communication. From a management point of view, it is critical to consider the needs and motivations behind the selected technology [30]. Currently, there are different families of ICT tools (email, video conferencing systems, chat, smartphone applications, social networks, blogs, wikis, virtual environments, etc.). Various specialized teaching tools integrate means of communication—both synchronous and asynchronous—, such as learning management systems or personal learning environments [34]. Since the people involved are from two distant universities, these tools will be the only instrument for collaboration. While face-to-face meetings should not be eliminated, they should be limited due to their economic cost [7, 21]. Most of the projects included in Table 1 did not use this type of meeting.

Stakeholders should not only be familiar with, but also have experience using the chosen tools (or at least be open to using them) [10, 24]. Even those students accustomed to using some of these technologies in their daily lives may need some guidance regarding their academic use. For example, students may be unaware of certain options which are useful for collaboration and promote the maximum benefit from the tool [35]. If participants are not familiar with the tool, they will need to invest time in learning about it.

One must choose the most appropriate tool for each situation [8]. However, this choice is not always obvious. Instructors need to select some channels of communication with the students of both subjects. This means will also serve to announce and present the tasks to the teams of students. In some of our experiences, a virtual classroom using the Moodle system, open to students and instructors from both universities, was employed in our research. Also, Google Suite and YouTube tools have been proved to be very useful in the interchange of documents, videos and peer review management. After experimenting with a tool, instructors should reflect on its

potential for such an activity, the difficulties encountered, and how to overcome them [3, 29].

3.2 Planning the experience

Once that the experience has been set up, the next step consists in planning the experience.

When organizing collaborative teams, one must consider how many students are participating at each university. Since, it is highly unlikely that the number of students at both universities match. Therefore, instructors must find some way to include all of them [10]. In our experiences, teams were pairs, one student from each university, and they were matched randomly. The remaining students (from the same university) were organized in pairs as well, and they did a similar task, except for the online component. This organization can cause problems if a student requests to be excluded from the telecollaboration teams (this may occur, for example, if the student thinks that there are necessary additional requirements). Other authors have applied the same approach [7], while still others have opted to organize mixed teams with a student from one university and several from the others [24]. See Table 1 for other types of student teams.

The definition and planification of tasks is a vital aspect in the design of any practical work. The identification and definition of the tasks requires coordination among instructors. It is important that instructors convey a common vision of the tasks to students at both institutions. Hence, the instructors need to explain to each other some of the concepts being addressed in their respective subjects. This communication involves investing time, which may affect the planning of activities. As students of both subjects may have very different prior knowledge of the issues to be addressed, they may require different explanations in the definition of tasks. In some cases, it may be necessary to introduce or expand some topic in the subject [8]. In addition, all changes in the definitions of tasks should be agreed upon by the teachers at both institutions.

To achieve satisfactory planning, one must realistically estimate the time needed to perform each task. In addition to the time required for the task itself, the time required for prior learning should also be estimated (e.g., concepts and examples shown in lectures). Typically, both issues meld, since the completion of the task serves in many cases as motivation to study the corresponding part of the course. Furthermore, one must keep in mind that online collaboration imposes additional time burdens that should be taken into consideration during planning [3, 6]. For example, it is necessary to spend time learning about unknown ICT tools, performing synchronous connections (telephone, video conference)—many of which are unsuccessful—or waiting for replies to message, among other reasons.

Another important point is to reserve time in task planning so that instructors can correct deliverables. Students should receive feedback as soon as possible [3]. Furthermore, in the case of chained tasks (the result of one task is the input for the next task) feedback is a crucial issue. If a student uses a defective deliverable as input for a task, the quality of this task's output will be reduced.

In our experience, the students were provided with a work breakdown structure (WBS), which represents the tasks hierarchically. They also received a Gantt chart, which places the development period of each task on the calendar. Moreover, the above-mentioned deadlines for completion of deliverables were established.

3.3 Executing

In this section, we focus on the execution of the telecollaborative tasks that the teachers have designed.

At the beginning of the practical work, we must provide the team members with a way of making contact with their partners. In our project, the students were provided with their partners' email addresses through a virtual classroom common to both universities. Therein, the instructions for performing the tasks were published. After the first year, the importance of proposing a very simple initial task whose main objective was precisely to establish and reinforce contact among the teams, became clear. Other authors also identify the need to generate trust, confidence and a shared identity during the first week of collaboration [19]. In any case, the aforementioned goals can be achieved in the medium term and require regular communication [19, 33].

After completing the initial organizational activities, students should be prepared to tackle the difficulties that may come up during the development of the tasks. The main challenge is coordinating with a partner at a distance. The team will not have regular contact in the classroom. So, the telecollaborator students do not personally know their teammates, how they behave normally, how quickly they reply to messages, how responsible they are, the interest that they have in the subject, if they will meet the deadlines established by the team, or what level of quality to expect from their work. At this point, each team should agree, at least, on how they will communicate (for example an asynchronous tool and a synchronous tool, appropriate response times, etc.), and how they will coordinate the tasks (who is responsible for each task, level of quality to be achieved, etc.).

Achieving regular communication within the team and selecting the appropriate channel for each situation is a considerable feat. Having tackled this, the team will still encounter more difficulties in communication. For example, with many tools the non-verbal cues (gestures, tone of voice, etc.) are lost (Redmond and Lock 2006). With asynchronous tools, communication may lose clarity [2]. Feedback can be delayed, prolonging the communication. In addition, students do not tend to be in the habit of exchanging sketches, arguments, ideas or alternatives with such tools. Moreover, synchronization problems can appear. For example, students need to reserve time to telecollaborate in their busy schedules, or decide which tools will be used each time. In addition, students often have many extracurricular commitments; thus, many tasks are left to the last minute. This habit has a particularly negative effect on telecollaboration, where extra time is necessary for coordination [21].

Another significant challenge is a joint understanding of the tasks to be performed by team members. Problems have also been detected when exchanging information and solutions obtained from diverse materials (books, notes, etc.) and from explanations provided by different instructors [7]. The subjects themselves may belong to different curricula, although they usually lead to equivalent degrees. All these obstacles imply that students have acquired different knowledge, skills and values through various instructional methodologies [20].

Telecollaboration is a complex process, that is different from face-to-face collaboration since it encompasses information technology skills as well as those pertaining to online interaction [6]. Students at traditional universities may have no experience with similar activities. Given that this was a new activity for the students, they were motivated; but as often occurs with change, they also showed some resistance to the unknown [36]. Initially, students resorted to communication patterns that work for them in classroom collaboration. However, developing communication methods more appropriate to telecollaboration can be convenient in this activity. To this aim, we must think about how to interact with peers via online tools and how to establish some basic rules for work and behavior.

Ideally students will understand as soon as possible what skills will be developed through the telecollaborative experience. Some experiences include discussions among instructors and students about telecollaborative skills, what difficulties can be expected, and how they might be overcome [20, 23]. Logically, the level achieved in this telecollaborative competency greatly affects the level of other generic and technical competencies to be improved through the activity [2, 6, 11]. In the generic competence type, these experiences led to the development of general strategies for teamwork, planning, organizing, applying, analyzing, creating and reflection. In the technical competence type, more specific skills such as programming or designing abilities are acquired in the case of computer science subjects. Instructors must decide whether students already have sufficient skills for telecollaboration, or if, on the contrary, they will develop these skills during the course [6].

In addition, there are numerous tacit rules among people who share the same culture, including regional peculiarities, or other factors specific to the university atmosphere. Many of those experiences in the literature have detected problems that are difficult to solve due to misunderstandings caused by cultural differences [7, 21, 23].

3.4 Monitoring and controlling

In addition to planning, it is also important to monitor and control students' execution of the tasks. In our experience, student teams asked questions or addressed their problems during classes, using virtual classroom forums or through institutional email. When adjustments in the planning were made, or errors were corrected in previously published documents, these three means (class, virtual class, email) were also employed.

The feedback sent to a student team should be consistent. It should follow the same format, and avoid, for example, sending a rubric to one team member and a simple numerical score to another. Furthermore, as several instructors are sending feedback almost simultaneously, they should agree on a way to reflect the evaluation results for all the phases. This idea of consistency takes on greater importance when different feedback must be sent to each team member. If both communications were to be compared, the information contained in them must be consistent.

We asked students about the time invested in the completion of each task, as well as the time spent in communication with their partner. The purpose was to analyze their time dedication and to adjust the time estimates in subsequent courses. The students were also asked on a regular basis if any problems had arisen related to the tasks.

It is also convenient to devise specific mechanisms for early identification of troublesome situations and disruptive students. For example, some students may fail to cooperate with their teammates. Once such a problem is detected, the problematic student should be excluded from the experience. In other words, instructors ought to focus their energy on supporting those responsible students. The physical distance between team members, the absence of regular contact, and the lack of timely answers

can leave a student without appropriate reaction mechanisms. Nevertheless, the ICT tools used in the telecollaboration allow inappropriate or unacceptable behaviors to be tracked [6].

As in the case of communication among students, instructors should also make an extra effort to maintain communication with their partners at a distance. They must also maintain communication with teams of students, for example addressing questions or assisting students when problems arise [3]. Technology enables communication and helps build confidence; nevertheless, it is apparent that geographic proximity surpasses everything that can be achieved through virtual meetings or phone calls [33]. Thus, face-to-face meetings in this type of practice should not be discarded [7]. Indeed, most of the projects included in Table 1 used these types of meetings. In our own experiences, the instructors involved (two per university) held two all-day face-to-face meetings. In the first meeting, the initial organization of the experience was established. The second meeting was dedicated to a final analysis of the experience. In addition, weekly phone conversations were held during the course of the project. These conversations lasted approximately from 30 to 60 minutes. Moreover, no less than two weekly emails were exchanged. Essentially, these emails aimed to review the documents published on the web for the students. As key deadlines approached, communication increased significantly.

3.5 Closing and analyzing

As such an experience is wrapping up, it proves extremely interesting to collect the results, evaluate them, and confirm whether the goals set at the beginning were achieved. Perhaps, the most obvious results are the academic ones. In our case, the grades obtained in the final exam and in the tasks completed throughout the semester were considered (rated from 0 to 10). Another type of result is related to student satisfaction. To this end, an anonymous questionnaire was prepared, inquiring about different aspects that include tasks execution, teammate behavior, and the communication process. The questionnaire included four-point Likert-type items ranging from zero points (for very bad or very little) to three points (for very good or a lot). Other outcomes such as the acquisition of generic skills could be included.

The results of our first experience are included in Table 2, which is extracted from the results obtained in [14]. These results showed that telecollaborators obtained statistically significant better academic results (with a medium effect size), but statistically significant worse satisfaction ratings (with a large effect size). The improvement in academic results can be attributed to the effort required of students to explain their own solutions to another person. This other person may not be very familiar with the subject, and may have to carry the baton in the next phase. Such an explanation requires reflecting on the task itself, which most certainly produces an increase in comprehension [37]. Regarding satisfaction, telecollaborators may have perceived that their task was more demanding than face-to-face collaborators. Extra effort is required by remote communication. The evaluation system also had a negative influence on satisfaction. The collaborative task affected the final mark in quite different proportions at both universities. In addition to the above, there could be other differences between the courses at both institutions, for example, if the activity is compulsory or optional. This type of situation can cause some students to believe that the level their team members' involvement is very different from their own and that the importance of deliveries and grades is greater for some than for others [21]. However, for a satisfying learning experience, it is meaningful to have more tolerance

Table 2. Academic results and satisfaction in Telecollaborators and Face-to-face students. Adapted from [14]

	Telecollaborators	Face-to-face	Telecollaborators vs. face-to-face	Effect size (Cohen's d)
N	36	56		
Academic results				
Mean (SD) grade	4.21 (2.52)	3.07 (2.08)	t = 2.280 df = 85*	0.49
% Pass exam	35.3	18.9	χ^2 = 2.958 df = 1$^+$	
Teamwork grade	4.53 (1.98)	4.27 (2.81)	n. s.	0.11
% Attendance rates	98.2	95.9	n. s.	
Satisfaction items				
Collaborative work	1.47 (0.84)	2.17 (0.82)	U = 544***	–0.84
Communication valuation	1.60 (0.88)	2.47 (0.80)	U = 419.5***	–1.03
Teamwork valuation	1.56 (0.86)	2.21 (0.64)	U = 594***	–0.86
Experience general valuation	1.33 (0.76)	2.00 (0.59)	U = 444.5***	–0.98

n. s. no significant p > = 0.1, $^+$p < 0.1, *p < 0.05, ***p < 0.001, t = t-Student test, U = Mann Whitney test.

to failure and encourage students' learning through a telecollaborative experience [30]. This approach could force to focus on the learning experience, and manage the production process in a flexible way, which can easily lead to a decrease in the quality of the final project, which cannot always be allowed.

Regarding the amount of time invested by students, there was a significant dispersion. While some students attested to complete the tasks and communicate with partner in less time than what was expected, others multiplied these times by a significant factor. These results complicate analysis and decision-making. Therefore, the questions on the form must be very precise, clearly distinguishing between performance, study, and communication times.

4. ICT technology

Collaboration and communication tools are critical components of telecollaboration [2]. There are different families of collaborative tools: a course management system—such as the official course platform (for example, Moodle or BlackBoard)—, synchronous communication tools (videoconferencing, Skype, or Google Hangouts), asynchronous communication tools (for example, Moodle forums, Facebook, email, or WhatsApp), document sharing (for example, Drive or Dropbox), collaborative writing (for example, Moodle wiki or Google Docs). From a management point of view, it is critical to consider the needs and motivations behind the selection of technology [2]. In addition, it is also important to have a set of technologies which can be offered at different phases of the collaboration [30].

Some teachers are in favor of requiring the use of specific communication tools for their students, such as virtual classroom forums [26]. The motivation behind such a requirement is probably the teacher's desire to supervise communication within the teams. But students may be more accustomed to other tools that are equally useful, or even better, for the intended purpose. In addition, it should be noted that the choice of the technology is strongly influenced by peers [38]. A requirement imposed by an instructor does not prevent students from using their favorite means of communication. To keep up appearances or meet the requirements indicated by the instructor, the student may post artificial messages from time to time in the mandatory tool. An example of this situation is found on [7] where at the beginning of the course, instructors organized videoconferences for students to get to know each other. However, students preferred to do so by email. In [21], instructors installed a version control system for each team of students, but the students preferred to utilize Google Docs instead. A sensible idea is proposed by [10] in which the teachers chose a wiki as the central online space for the project and this tool is used as initial communication channel. But, after that, teams could decide to use other communication channels and online tools for working on their team tasks. The visibility of this initial phase was important for the teachers to be able to see that the teams were all up and running.

In our work [14–16], the different kinds of interaction between students, between teachers, and between students and teachers were observed. The problems that arose were similar both for teachers and students. These problems came about, for example, when making decisions, working on teams, and meeting deadlines. However, there were differences in the way students and teachers dealt with those problems and the tools they used.

Instructors mainly used institutional email, and a virtual classroom as a mean of asynchronous communication. The primary mean of synchronous communication was the institutional phone. Occasionally, audio and video conferences were organized. Two all-day meetings were held each academic year, as mentioned previously. Albeit subjectively, the instructors felt comfortable and pleased with these tools [14].

After analyzing the communication channels used by the students, it should be noted that email was the most frequent tool, followed at some distance by social networks. Synchronous tools such as chat and audio and video conference were utilized less frequently. In general, students reported low satisfaction with communication [14]. The predominance of email may be due to several factors. Firstly, email was the mean chosen to establish initial contact between the teams (one student from each university). To that end, they were asked to exchange email addresses. In addition, email is usually the common communication channel with instructors. Furthermore, it seems that students prefer to distinguish channels of leisure and of work. Therefore, we may conclude that students perceive that both the phone and social networks pertain to their personal life. The immediacy provided by these tools in obtaining response, as compared with email, and the anxiety that slow response time may produce may have been the principal cause of low satisfaction [8].

In other experiences, such as that described in [7], email was also the most widely employed option. At this university, students also used the email system, provided by the learning management system, to collaborate in teams. The Skype video conferencing system was utilized to hold team meetings and

Google Docs for putting together the final report. These tools were also used in the experiences reported in [21], along with the version control system repository created for each team. Also, in [2] the communication by means of email is still preferred, in spite of existing social and more user friendly tools. In this last work [2], video conference and the use of Google technologies are also used. See Table 1 for a description of the tools used in other projects.

5. Institutional context

In the present case, universities are the backdrop for these experiences. And based on these experiences, it has been observed that the institution should not be the promoter of telecollaboration projects [29, 33]. However, there may be academic rules, drawn up without considering such initiatives that can interfere or hinder their organization [29]. To arrange telecollaboration between universities, personal contact between instructors appears to be the most effective means [29, 33]. Academic institutions, on the contrary, usually do not grant much recognition to such initiatives.

Currently, a culture of flexibility and innovation is growing in the universities [4]. Many have, for example, institutional programs to promote educational innovation or to exchange students. These programs encourage and facilitate the development of educational initiatives such as those presented herein. In addition, universities have other cooperation channels, especially in the field of research. Access to university facilities and the use of its resources (meeting rooms, computers, etc.) by visitors from other universities is usually fairly flexible [20]. And while during periods of economic difficulty, strong financial support for this type of activities cannot be expected, a minimum level of funding is essential to, for example, cover travel expenses associated with meetings.

Among the institutional conditions that may hinder the implementation of telecollaboration projects, are the often extremely rigid rules for evaluation [29]. For example, many universities establish that all subjects must include a final exam comprising 100% of the course grade. This examination may constitute an alternative allowing students to circumvent the telecollaboration task. Another example is the alternative ways of obtaining credits established by universities, with which students can bypass certain subjects [7]. Other elements that may have a negative impact on telecollaborative initiatives are: assessment of the instructors' quality of work, usually measured by satisfaction surveys completed by the students; or the mandatory use of institutional educational platforms. Let us assume that the instructor offers interesting tasks for the student's education and learning but that are unpleasant to perform. By using traditional tools to measure satisfaction, where this type of situation is not considered, the result can be very similar to that obtained by a negligent or careless instructor. These negative results can also adversely impact recognition of the instructor's work and his or her desire to innovate in the teaching of their subjects in the future.

6. Discussion

One way to introduce the competence of remote collaboration through ICT tools in traditional universities is to organize telecollaborative experiences between students from two distant universities [3]. To design and monitor this type of experience, appropriate models, guides, and examples of lessons learned can be of significant assistance.

Some telecollaborative experiences are included in the literature dealing with several obstacles. The most noteworthy challenge is the time it takes to adapt to this way of working [3]. For example, communication is established using tools that reduce non-verbal communication [2, 14]. Also the task of coordination, and communication itself, requires a greater time investment than face-to-face contact [29]. For educators, telecollaboration also implies a certain loss of control over their subject. It may also be difficult to find suitable instructors with whom to collaborate [29]. Moreover, an improvement in academic results or in student satisfaction does not readily justify instructor satisfaction. Rather, an instructor's satisfaction is found on the learning achieved by students through peer collaboration, the introduction of innovations, and the possibility of turning the experience into a research study [4]. The effort required for this type of experience is significant. Thus, linking the collaborative work to research to achieve external recognition is an interesting option. Nevertheless, the latter idea is not so straightforward, since it requires tasks designed exclusively for research, such as data capture, or the design and realization of surveys. Such work may interfere with an instructor's effort to improve student learning, provide feedback on time, or correct errors. However, innovations in the area of teaching are aligned with other innovations and changes occurring in fields such as technology and industry. Therefore, scholars should, to some extent, research teaching practices [8].

The different experiences found in the literature reveals many commonalities regarding the most convenient way to guide these collaborations. For instance, the planning of tasks must take into

account the different calendars and the varying levels of interest to cooperate in describing the activities [3, 7, 21, 20]. Furthermore, instructors ought to reflect with students on the most appropriate tools for each task or even offer training on the use of concrete tools or appropriate functionalities [2, 8].

There are also some differences among experiences relayed in the literature (see Table 1). For example, collaboration can be between pairs of students (one from each university), or one student collaborates with several students from another university; the type of activity or the tools used; and whether or not face-to-face meetings between students or instructors are held, etc.

The development of telecollaborative experiences is facilitated by ITC tools, that progressively incorporate new facilities and are widespread for the whole population in their daily lives [2]. Different ways of taking advantage of these possibilities, when dealing with experiences of telecollaboration, have been considered from very different approaches, methods and objectives [2, 10, 21, 23]; however, they have not consolidated standardized ways of proceeding. Our trajectory of interuniversity telecollaboration systematically deployed over the years, allows us to raise as critical aspects the instructors' planning and coordination, a requirement for the successful and continued deployment of the experiences of telecollaboration. The evolution, progressive extension, and ease of use of computer tools allow us to focus more on the working methods than on the characteristics of the tools, and these tools are more than enough to put into practice various alternatives of telecollaboration based on work in distributed teams [14], the exchange of feedback [15, 17] or the exchange and integration of materials [16].

In general, there are few empirical studies on telecollaborative experiences and it has yet to be established what is most convenient throughout the different phases. Possibilities abound for future empirical studies. For example, one may investigate, regarding satisfaction or the quality of the deliverables, what type of collaboration offers better results depending on the number of members on each team from each university. And yet another option for future research would be which tool leads to better results for each type of activity.

The model that we propose in this paper could have the following limitations. It has been built on collaboration made between students which share a common language. International telecollaboration among students with different mother tongues should carefully take this aspect into consideration. In addition, although the model has been successfully put into practice for almost a decade between two different Spanish Universities in Computer Science disciplines, it should be proved in other countries and disciplines.

7. Conclusions

In the context of higher education, due to globalization, graduates need to be able to work comfortably in an increasingly distributed team context. Therefore, it is important that students can telecollaborate in a team making effective use of ICT tools. One way to introduce the competence of remote collaboration through ICT tools in traditional universities is to organize telecollaborative experiences between students from two distant universities. The primary benefits that students can gain from these experiences include: learning different ways to collaborate, gaining experience with proper tools, or collaborating with students from different backgrounds. Educators, in turn, contact other teachers, exchanging views and ways of working. Thus, creativity and innovation in teaching is promoted. To design and monitor this type of experience, appropriate models, guides, and examples of lessons learned can be of significant assistance. In this work, we have presented a telecollaboration model approach between engineering students and instructors from two distant traditional universities which has been successful applied along several years. Potentials, difficulties and key elements are identified to promote an experience that is feasible, effective—regarding the intended objectives—and sustainable over time. We understand the organization of a telecollaborative experience as the development of a project, and we have structured the experience through the five processes typically identified in such development: initiating, planning, executing, monitoring and controlling, and closing processes. Also, reflections on technological aspects and the role of university institutions are included. This model is intended to aid in the organization of experiences in different contexts, and it may serve as a guide to deal with the frequently occurring issues, along with some ideas to solve and even avoid them.

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References

1. A. Díaz and J. Márquez, Towards global engineers: Challenges and strategies for promoting international mobility in engineering education, *International Journal of Engineering Education*, **33**(6), 2017, pp. 1995–2007.
2. I. E. Esparragoza, S. L. Farak, J. R. Ocampo, J. N. Segovia, R. Viganò, J. Duque-Rivera and C. A. Rodriguez, Assess-

ment of students' interactions in multinational collaborative design projects, *International Journal of Engineering Education*, **31**(5), 2015, pp. 1255–1269.
3. J. Harris, First steps in telecollaboration, *Learning and Leading with Technology*, **27**(3), 1999, pp. 54–57.
4. R. O'Dowd, Emerging trends and new directions in telecollaborative learning, *Calico journal*, **33**(3), 2016, pp. 291–310.
5. N. Capdeferro and M. Romero, Are online learners frustrated with collaborative learning experiences?, *International Review of Research in Open and Distance Learning*, **13**(2), 2012, pp. 26–44.
6. J. Macdonald, Assessing online collaborative learning: process and product, *Computers and Education*, **40**, 2003, pp. 377–391.
7. C. Laxer, M. Daniels, Å. Cajander and M. Wollowski, Evolution of an International Collaborative Student Project, *Proceedings of the Eleventh Australasian Conference on Computing Education*, 95, Wellington, New Zealand, 2009, pp. 111–118.
8. P. Redmond and J. V. Lock, A flexible framework for online collaborative learning, *The Internet and Higher Education*, **9**(4), 2006, pp. 267–276.
9. J. Grimson, Re-engineering the curriculum for the 21st century, *European Journal of Engineering Education*, **27**(1), 2002, pp. 31–37.
10. R. Lindner, Developing communicative competence in global virtual teams: A multiliteracies approach to telecollaboration for students of business and economics, *CASALC Review*, **1**, 2016, pp. 144–156.
11. M. Vallance, S. Martin and C. Naamani, A situation that we had never imagined: post-Fukushima virtual collaborations for determining robot task metrics', *International Journal of Learning Technology*, **10**(1), 2015, pp. 30–49.
12. W. R. Varuna and S. Palanisamy, The Contribution of Information and Communication Technologies in Education Development the Applications of ICTs, *Bonfring International Journal of Software Engineering and Soft Computing*, **2**, 2012, pp. 22–25.
13. B. Stone, S. E. Gorrell and M. Richey, Profile-Based Team Organization in Multi-University Capstone Engineering, *International Journal of Engineering Education*, **34**(2A), 2018, pp. 414–429.
14. A. Jaime, C. Domínguez, A. Sánchez and J. M. Blanco, Interuniversity telecollaboration to improve academic results and identify preferred communication tools, *Computers and Education*, **64**, 2013, pp. 63–69.
15. C. Domínguez, A. Jaime, A. Sánchez, J. M. Blanco and J. Heras, A comparative analysis of the consistency and difference among online self-, peer-, external- and instructor-assessments: The competitive effect, *Computers in Human Behavior*, **60**, 2016, pp. 112–120.
16. A. Jaime, J. M. Blanco, C. Domínguez, A. Sánchez, J. Heras and I. Usandizaga, Spiral and Project Based Learning with Peer-Assessment in a Computer Science Project Management Course, *Journal of Science Education and Technology* **25**(3), 2016, pp. 439–449.
17. A. Sánchez, C. Domínguez, J. M. Blanco and A. Jaime, Incorporating Computing Professionals' Know-how: Differences between Assessment by Students, Academics and Professional Experts, *ACM Transactions on Computing Education*, 2018, Preprint.
18. Project Management Institute, *A Guide to the Project Management Body of Knowledge (PMBOK® guide)*, Pennsylvania, 6th ed. 2017.
19. P. Díaz, P. Acuña, I. Aedo and R. Ocker, The impact of working in Partially Distributed Teams, *Global Engineering Education Conference (EDUCON)*, Amman, Jordan, 2011, pp. 358–365.
20. S. Al-Janabi and W. Sverdlik, Towards long-term international collaboration in Computer Science education, *Global Engineering Education Conference (EDUCON)*, Amman, Jordan, 2011, pp. 86–90.
21. A. Chidanandan, L. Russell-Dag, C. Laxer and R. Ayfer, In their words: student feedback on an international project collaboration, *Proceedings of the 41st ACM Technical Symposium on Computer Science Education*, Milwaukee, Wisconsin, USA, 2010, pp. 534-538.
22. P. Rohleder, V. Bozalek, R. Carolissen, B. Leibowitz and L. Swartz, Students' evaluations of the use of e-learning in a collaborative project between two South African universities, *Higher Education*, **56**, 2008, pp. 95–107.
23. D. Malinowski and C. Kramsch, The ambiguous world of heteroglossic computer-mediated language learning, in A. Blackledge and A. Creese (eds), *Heteroglossia as Practice and Pedagogy*, Springer, Dordrecht, 2014.
24. J. Hilburn and B. Maguth, Intercollegiate collaboration: Connecting social studies preservice teachers at two universities, *Contemporary Issues in Technology and Teacher Education*, **12**(3), 2012, pp. 308–327.
25. S. Guth, F. Helm and R. O'Dowd, University language classes collaborating online: A report on the integration of telecollaborative networks in European universities, [Online]. https://www.unicollaboration.org/wp-content/uploads/2016/06/1.1-Telecollaboration_report_Executive_summary-Oct2012_0.pdf, 2012, Accessed September 2018.
26. P. D. Ware and R. O'Dowd, Peer feedback on language form in telecollaboration, *Language Learning and Technology*, **12**(1), 2008, pp. 43–63.
27. R. D. Francescato, R. Porcelli, M. Mebane, M. Cuddeta, J. Koblas and P. Renzi, Evaluation of the efficacy of collaborative learning in face-to-face and computer-supported university contexts, *Computers in Human Behavior*, **22**, 2006, pp. 163–176.
28. J. L. Tutty and J. D. Klein, Computer-mediated instruction: a comparison of online and face-to-face collaboration, *Educational Technology Research and Development*, **56**, 2008, pp. 101–124.
29. R. O'Dowd, Telecollaborative networks in university higher education: Overcoming barriers to integration, *The Internet and Higher Education*, **18**, 2013, pp. 47–53.
30. Å. Cajander, M. Daniels, C. Kultur, L. R. Dag and C. Laxer, Managing international student collaborations: An experience report, *Frontiers in Education Conference (FIE)*, Seattle, Washington, 2012, pp. 1–6.
31. M. J. Amey, P. L. Eddy and C. C. Ozakim, Demands for partnership and collaboration in higher education: A model, *New Directions for Community Colleges*, **139**, 2007, pp. 5–14.
32. P. L. Eddy and R. L. G. Mitchell, Faculty as Learners: developing Thinking Communities, *Innovative Higher Education*, **37**, 2012, pp. 283–296.
33. S. Duffield, A. Olson and R. Kerzman, Crossing borders, breaking boundaries: Collaboration among higher education institutions, *Innovative Higher Education*, **38**(3), 2013, pp. 237–250.
34. P. Häkkinen and R. Hämäläinen, Shared and personal learning spaces: Challenges for pedagogical design, *Internet and Higher Education*, **15**, 2012, pp. 231–236.
35. P. Thompson, The digital natives as learners: Technology use patterns and approaches to learning, *Computers and Education*, **65**, 2013, pp. 12–33.
36. I. Mitchell and A. Carbone, A typology of task characteristics and their effects on student engagement, *International of Educational Research*, **50**(5), 2011, pp. 257–270.
37. D. R. Krathwohl, A Revision of Bloom's Taxonomy: An Overview, *Theory into Practice*, **41**(4), 2002, pp. 212–218.
38. R. Cheung and D. Vogel, Predicting user acceptance of collaborative technologies: An extension of the technology acceptance model for e-learning, *Computers and Education*, **63**, 2013, pp. 160–175.

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