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Assessment of Students' Interactions in Multinational Collaborative Design Projects*

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Exposing students to international experiences is becoming a common practice to prepare students with global capabilities. One pedagogical activity used to promote global competencies is the participation of students in multinational design projects. This is a problem-based learning approach in an international setting, where students get immersed in the solution of an engineering design task while they work in teams and collaborate with international partners. The main goal of these projects is to foster international collaboration and to offer an opportunity to the students to develop professional skills through international teamwork effort in the solution of a design problem. However, a real challenge of this practice has been to create an effective interaction among the students participating in this type of projects and to maintain the flow of information, and student engagement in the project and in their learning. The main objective of this work is to investigate the sociotechnical interaction of engineering students working in a multinational collaborative project and the role of information technology tools and the nature of the interaction in this experience. For this purpose an assessment tool was developed and used to determine the interaction among the students (frequency, quantity and quality), the value of social interaction in the flow of the interaction, and the impact of the interaction in the development of the project. The main findings of this instrument are presented in this work.

Keywords: collaborative projects; international collaboration; global teams; interaction assessment

1. Introduction

Globalization has changed many aspects of people's daily lives and has created different working environments and practices in many corporations. Competition is fierce and in order for firms to thrive, time to bring products to markets has to be shortened, quality of products has to be increased, and costs must be tightly controlled. These demands have forced companies to go through acquisitions and mergers, strategic alliances and the search for resources and human talent around the world and the consequent formation of globally dispersed teams [1]. The practice of teams formed by members geographically dispersed working on common projects is becoming very common due to the advancements in information and communication technologies (ICT) and the development of team-based structures as part of the organizations [2]. The obvious advantage is that these teams can hypothetically reduce time of development of new products, increase organizational performance and improve employees' participation due to the synergy that can be obtained [3].

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Engineering design practice has also evolved towards a distributed design thanks to the flow of information shared through electronic means [4]. In fact, product design is mainly considered now a team effort in which groups of experts from many disciplines work together [5]. Nowadays, these experts are often globally dispersed and interact by means of several communication tools. However, these teams face many challenges including differences in time zone, language, national traditions, values and norms of behavior [6]. Moreover, the collaboration always raises new issues about the control of the various elements of the design process to ensure, for example, that decisions made are recorded and transmitted to all the process actors [7].

The interest in this practice has promoted the development of tools able to satisfy the increasing requests of global collaborative design. These collaborative tools also "allow designers to work closely with suppliers, manufacturing partners, and customers across enterprises' firewalls to get valuable input into the design chain" [8]. Next to these tools which could be included into the specific professional domain sphere, nowadays there are many different systems able to support the communication [9] which belong to the wider domain of the social media tools. Social and traditional media become thus part of a system whereby all elements work together towards a common objective. For this, companies need to consider these tools to engage designers in interactive dialogues [10].

These new trends require people who know and are able to use collaborative tools as well as technicians able to manage and actively participate and contribute in collaborative projects. Engineering schools must be aware of these new tendencies and should promote and facilitate an educational environment to prepare students with the theoretical foundation and the necessary experiences to be competitive in the global economy and to be ready to work in global collaborative environments. In addition, the abilities to design, communicate and work effectively in multidisciplinary teams, and to use modern engineering tools, are recognized by engineering accreditation bodies as key student outcomes [11]. For this, new educational models, which expose students to multidisciplinary and global collaborative experiences, should be adopted to educate future engineers.

In response to the call for alternative educational experiences, the use of project-based learning approach (PBL) has become a common practice in academic environments. This method of study is inductive [12] where students seek solutions to open problems by formulating research questions, planning design, collecting, analyzing and synthesizing information, building models, and creating artifacts or products of their understanding. This learning context involves both vertical learning (referring to the accumulation of knowledge of the subject) and horizontal learning (referring to generic competencies such as project management, social skills and collaboration) [13]. A principle of the educational psychology affirms that students are strongly motivated to learn things they clearly perceive as things they need to know [14]. Therefore, it is critical to emphasize to the student the importance of this learning approach in the development of knowledge and skills needed in their future professional work.

The use of multinational collaborative design projects in the academia is a problem-based learning approach in an international setting. In this type of projects, students are immersed in the solution of an engineering design task while they work in teams and collaborate with international partners. The main goal of these projects is to foster international collaboration and to offer an opportunity for students to develop professional skills through international teamwork effort in the solution of a design problem.

A real challenge of this practice has been to create an effective interaction among the students participating in this type of projects and to maintain the flow of information, and student engagement in the project and in their learning. Therefore, this paper reports the work related to an assessment approach used to monitor students' interaction in multinational collaborative projects. The main objectives of the proposed assessment tool are: (a) to evaluate the interaction among the students (frequency, quantity and quality); (b) to determine the value of social interaction in the flow of the interaction; (c) to determine the impact of interaction in the development of the project.

2. Background

Among the difficulties associated with having globally dispersed teams are the typical complexities of working with others, especially with people from different cultures and functional backgrounds. Scott & Einstein [15] indicate that another issue to be concerned with is the transitory nature of global teams, which means that members can be part of several teams at once and this can create problems due to different forms of recognition and rewarding systems among teams. Another difficulty has to do with how to measure individual effort or job performance under this setting [16]. This lack of structure can create misunderstanding among team members and management as well as frictions.

If managing a team of people globally dispersed has its issues, it also has its benefits. To design and manufacture new products with the constraints in time and quality previously described there is a need of expertise in different fields so those products can achieve the characteristics required by its customers. In fact, because conceptual design is a task highly interdisciplinary, requires collaboration from customers, designers and engineers who are usually located in different parts of the world [17]. One of the ways in which these issues can be addressed is through the use of collaborative product development (also known as cooperative design, concurrent design and inter-disciplinary design). This type of collaboration allows for different experts to participate in the solution of the problem.

According to Davidow & Malone [2] due to the advancements in information and communication technology (ICT) this collaboration can be in geographically dispersed places with experts working in a collective and joint way. A company then does not require having all the members of a team located in one place, and it can utilize all the resources available regardless of their location. Wilczynski & Jennings [18] suggest that this type of teams are known as "virtual" teams because their work is predominantly done through electronic ICT tools such as email and video-conferencing [19, 20]. They point that these teams are also known as collaborative learning groups, non-collocated teams, geographically and temporally dispersed teams, and globally distributed teams among others. The use of these types of teams allows for concurrent engineering reducing in this way the elapsed time required to convert an idea into a product.

According to Gibson & Cohen, [21] and Hinds & Kiesler, [22] most of the larger corporations use virtual teams. In fact, according to AFW in Hertel, Geister, & Konradt, [19] a survey among 376 business managers from different companies in Germany showed that 20% of them worked mainly as part of virtual teams and about 40% of them had worked at least temporally in them. This same trend is true in the automotive manufacturing industry [23], banking corporations [20] and other fields, since the use of global virtual teams (GVT) is not exclusive to engineering and business administration, but also to science in general [24]. In fact, the Gartner group predicted that by 2004 more than 60% of the professional workforce in the Global 2000 companies will work using virtual groups [1].

2.1 *Multinational teams interactions*

Universities and particularly schools of engineering have recognized the need that their students acquire the competencies required to participate effectively in global collaborative teams. Many of them understand that the use of collaborative projects as learning experiences will allow them to become more competitive in a global world [25–27]. These types of projects are developed in the context of a problem-based learning experience but in an international setting. There are several examples of universities that have joined together to work in collaborative product design projects so students can learn in that way regarding the benefits and challenges of this type of work configuration. Other universities have focused in the development of tools that facilitate the interaction and collaboration among teams.

An example of collaborations among universities is the European Global Product Realization Project (E-GPR) which brought together the Swiss Federal Institute of Technology of Lausanne (Switzerland), the Technical University of Delft (Netherlands) and the University of Ljubljana (Slovenia). The objective of the E-GPR was to expose students at the experience of solving a global product development project using the knowledge acquired during the course, the knowledge learned in previous classes and the information and data obtained by their industrial partner [17] and [1]. Other examples include the CADAU (Computer Aided Design Across Universities), which is an international collaboration project between the computer-aided design courses at Iowa State University (ISU) in the United States and the University of Technology of Compiegne (UTC) in France[28], the ICON (Institutional Collaboration Over Networks) between students from the Product Design Courses at University of Strathclyde and the University of Glasgow, both in Scotland [29], and the Global Design Project developed among LACCEI Institutions [25–27], among others.

2.2 *Assessment of interactions*

One of the requirements for a global virtual team to be successful is that the team members are capable and committed [30, 31]. The required competencies of each team member will depend on the specific goals of the team. The trust among teammates required to foster the spirit of cooperation needed to successfully accomplish the team's objective can be built on the consistent good behavior of the individuals [32]. In contrast, bad behavior such as lack of communication, low level of individual accountability, lack of commitment toward quality work, etc. yields low trust among team members jeopardizing teamwork effectiveness [33]. Therefore assessing the behavior of team members in their interaction and the fulfillment and completeness of their assigned task is very important.

Since good communication is pivotal to success in GVTs, another requirement to success is having the right tools so team members can work collaboratively [20]. According to Gibson & Cohen [21] this communication is more often done through email or conference calls (first generation technology). However, as Lee-Kelley, Crossman, & Cannings [34] and Maznevski & Chudoba [35] explain, some level of face-to-face interaction is also neccesary to enhance the communication and trust. This type of communication can be done physically or using ICT tools (second or third generation technologies) such as video-conferences and web-enabled shared workspaces via intranet or internet. Although some researchers suggest that this type of interaction can be counterproductive as highlights the differences between members and can produce bias and affect future communication between team members [36], the majority of research seems to support the positive effect that face-to-face communication has in the performance of GVTs [37].

According to Hosseini & Chileshe [38], communication is one of the great challenges that GVTs face. The quality of this communication is affected by the type of ICT being used to share knowledge (ideas, concepts, models, etc.) and by the infrastructure available to support it [39]. Other factors to take into consideration is the time differences between team members which would require capabilities for asincronous communication, difference in language and culture, and the need to measure contribution and involvement of team members [40, 41]. Due to the importance of this interaction, universities such as Syracuse University, University of Hong Kong and Lancaster University have been working in research projects with the aim of developing web-based collaborative design systems and tools under a client-server architecture. Likewise, Carnegie Mellon University, University of California Berkeley, University of Tennessee at Chattanooga and Stanford University have been working in similar tools using an agent-based collaborative design approach [42].

An academic collaborative product design project is an instructional strategy designed to encourage students to work in global groups towards accomplishing a goal. This strategy creates a learning environment where knowledge is shared or transmitted among team members [43]. According to Palloff & Pratt [44], collaborative learning (and therefore academic global virtual teams) have pedagogical benefits such as the development of critical thinking skills, co-creation of knowledge and meaning, reflection, and transformative learning. Siemens, [45] suggests that these benefits are accomplished through a four stage continuum composed of communication (people talking and discussing), collaboration (people sharing ideas and resources, as well as working together), cooperation (people doing things together) and community (people striving for a common purpose).

As an education tool, academic collaborative product design projects require an assessment to gather feedback on the learning process of the students. The information gathered should then be used to improve the teaching-learning process taking place [46]. Therefore, the assessment of the quality of the interaction in a global collaborative experience should be measured incorporating in its metrics the areas previously discussed.

2.3 Objectives and research questions

Of particular interest for multinational collaborative projects is to improve the interaction among students so they have a constant flow of information for the project and increase their motivation in getting engaged actively in this learning experience. Therefore, it is important to understand the dynamics of the interaction to enhance the experience. This work is founded on the idea that appropriate interaction at social and professional level will positively contribute to the successful completion of tasks for teams geographically dispersed. Based on this notion, the main objective of this study is to investigate the sociotechnical interaction of engineering students working in a multinational collaborative project and the role of information technology tools and the nature of the interaction. The following research questions lead this study: (a) what is the level of interaction among students in terms of frequency and quantity? (b) What is the nature of the interaction? (c) What are the preferred tools used for communication? (d) Does social interaction contribute to the flow of the information during the project? (e) What is the impact of the interaction in the development of the project?

2.4 Multinational collaborative project

To reach the goals of this work, a global collaborative design project was established among institutions in Chile, Colombia, Ecuador, Honduras, Italy and USA. The design of the international collaboration experience followed a systems model design, including contextual factors, process-input factors, team dynamics, and affective moderators all of them affecting the team's performance [47]. The collaborative project reported in this work follows the parallel design approach where teams in each country work on the same project and they have to share and discuss data and information with their international peers to enhance the final solution. For this purpose, a collaborative network among teams geographically dispersed was formed creating virtual teams composed of sub-groups by location as shown in Fig. 1. Teams form six collaborative clusters where they interact with international

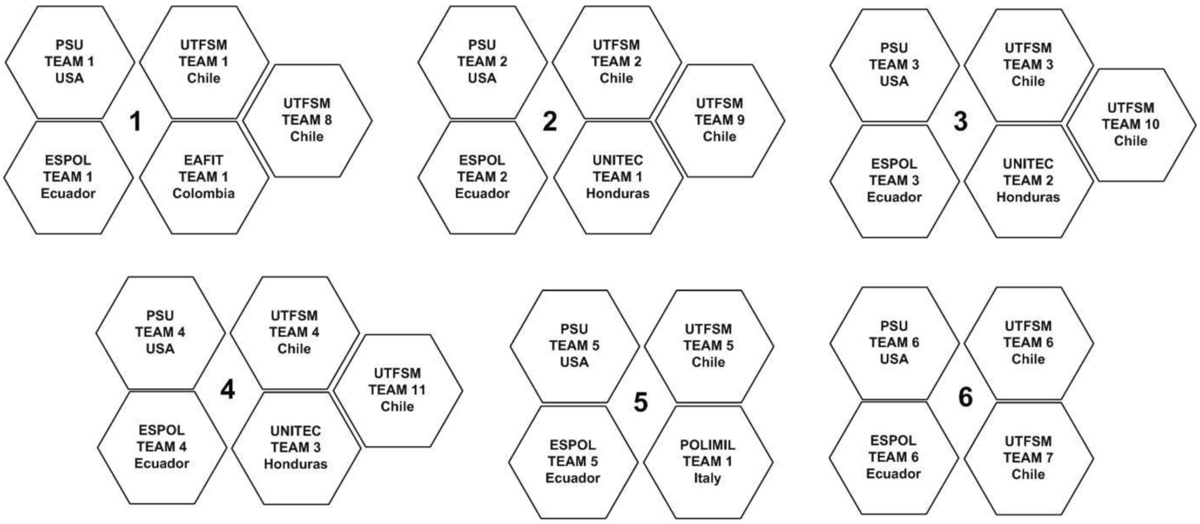


Fig. 1. Collaborative Network of Multinational Design Projects

teams to solve the design challenge. The collaborative project consisted in the design of a machine to produce and pack tropical dried fruits (Cantaloupes) in bags of 250 grams. The main requirements given to the teams were: capable of processing one ton per day; low cost of manufacturing, operation and service; system to be manufactured in Latin America; operation and maintenance to be carried out by a cooperative in Colombia. The project was structured to last eight weeks and the instructions given to the students also included clearly stated descriptions of project goals and deliverables as these are recognized to moderate differences in culture with regards to perceptions of time, conflict and risk management (op. cit). Technical expertise was not considered a factor as all participants were first or second year engineering students. Virtual sessions were scheduled weekly using an online meeting room made available by one of the partner institutions. Recommendations of having continuous interaction with the international partner groups that composed the cluster were also provided. This was done to foster interaction among participants, to determine the sociotechnical interaction of the students and to answer the research questions of this investigation.

3. Methodology

The multinational collaborative design project used as a learning tool needs to be evaluated to gather information about the teaching-learning process and use this information to make improvements [46] . In this investigation, the experience was evaluated through an "*ad-hoc*" instrument to determine the frequency, quantity and nature of social interaction, the preferred communication tools, the effects of this global collaborative project and basics demographic information

3.1 Participants

In this study, data was collected from 100 students participating in the global collaborative project. These participants were primarily first and second year engineering students from different fields. The participants consist of (82%) male and (18%) female having the following geographic distribution: Chile (34), Colombia (3), Ecuador (28), Honduras (6), Italy (5) and USA (24) as shown in Fig. 2.

Most of the participants (69) acknowledge that their scholar experience (know-how) was adequate to participate into this collaborative experience (Fig. 3).

3.2 Instrument

The questions of the instrument were grouped into five categories: I. *Demographic Questions*: (2 items) on basic information such as gender and location (country). II. *Interaction means used, frequency and nature*: (5 items) in order to determine the most used means of communication, how often they interacted

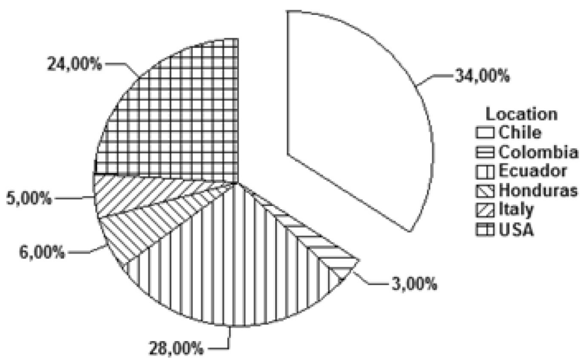


Fig. 2. Location distribution.

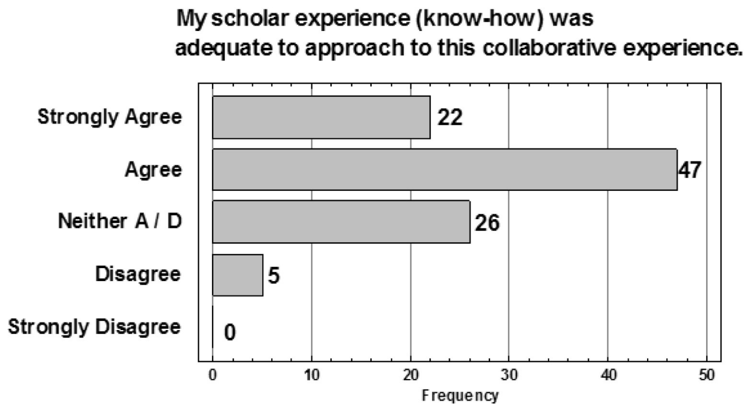


Fig. 3. Individual preparedness for collaborative experience.

with international partners using ICTs, how often they attended scheduled meetings, hours spent and what kind of contact information was shared. III. *Evaluation of collaborative experience*: (17 items) questions focused on the amount of information given and received, quality and usefulness of information received, usefulness of the collaborative experience, and personal willingness to collaborate and team commitment. Responses for each one of these items were rated by using a five-point Likert scale (Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree). IV. *Purpose of interaction for the project*: (2 items) to know what kind of information regarding the project was shared and whether the information received from international partners contributed to complete the project. V. *Open questions*: to inquire what they did well as a team, what problems encountered and suggest improvement actions.

3.3 Procedure

The student questionnaire was performed after they had completed the project. The survey was designed to be completed online using a portal located in www.qualtrics.com. Students were told that their participation was voluntary, that non-participation would not affect their academic results or future studies, and that all information would be confidential.

3.4 Statistical analysis

Descriptive statistics was performed using STATGRAPHICS Centurion XVI and Statistical analysis was undertaken using the Statistical Package for the Social Sciences (SPSS), version 19.0.

The validity and reliability of the instrument were evaluated using the entire study sample (n = 100) for the 17 items of the section III. (*Evaluation of collaborative experience)* as follows: The questions were validated among all teachers participating in the project to ensure that all elements wanted to be studied were taken into account.

The internal consistency was established by calculating Cronbach's alpha coefficients and the intraclass correlation coefficient [48]. Construct validity was established by principal component analysis [49]. The factor structure of the section III was examined by exploratory principal component analysis with Varimax rotation and Kaiser.

4. Findings and discussion

The results of the survey that addresses relevant indicators necessary to determine the frequency, quantity and nature of social interaction, preferred communication tools and effects of this global collaborative project are presented.

4.1 Frequency, quantity and nature of social interaction

The frequency, quantity and nature of social interaction were measured in terms of:

- Frequency of interaction using ICTs
- Quantity or time disposed to attend the activities and work with the international partners
- Equitable contribution of the teams and their willingness with the work
- Type of information shared during the project

Concerning to the frequency in the use of ICTs, the results show that 48% of the participants interacted sometimes (3–5 times) with international partners using any means of communication. It also shows that 19% interacted often (5–10 times) and 6% interacted very often (>10 times), as is illustrated in Fig. 4(a). The frequency of meeting attendance reflects that 40% of the participants always attended, 38% did it often or very often and only 3% never attended (Fig. 4(b)). In relation to the time disposed to the project, Fig. 4(c) shows the time spent working with international partners: 49%

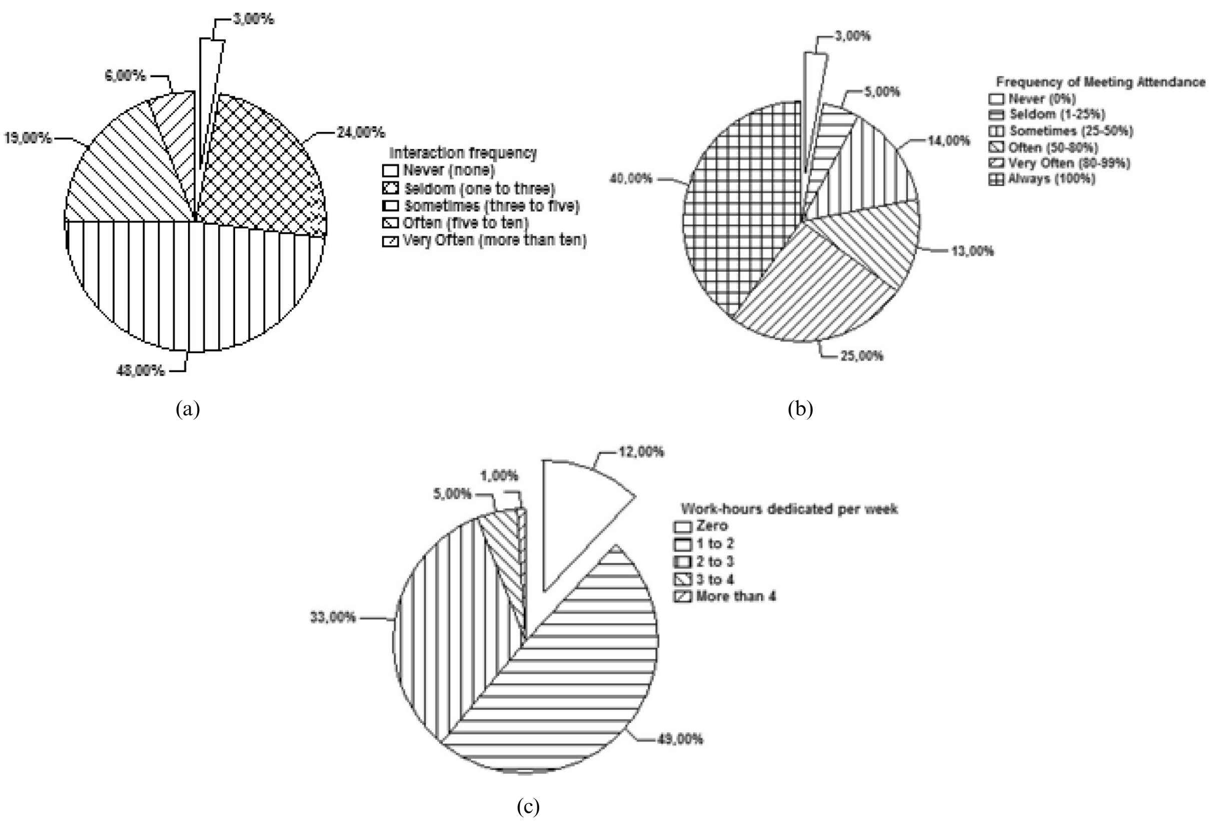


Fig. 4. Frequency of meeting attendance: (a) interaction frequency; (b) frequency of meeting attendance; (c) hours dedicated to work with international partners.

spent around 1–2 hours per week, 33% among 2–3 hours and 12% did not dedicate time to work with their international partners.

In this project, the students needed to use at least one hour per week to attend a scheduled meeting. Fig. 5 shows the results of the adequacy of the amount of time used before and during the Videoconference. Most participants (61%) recognize that the amount of time before the meeting, during the meeting (Videoconference) and the one scheduled to develop each assignment was adequate. However, 6 students agreed that the time provided before the meetings was insufficient, and 17 participants acknowledge that the time allocated for scheduled meetings (Videoconference) was limited/little.

Regarding to the equitable contribution of the teams in the cluster, Fig. 6 shows the frequency of equal contribution of all teams in the cluster. About half of the participants (51%) considered that all the teams in their cluster contributed equally to the

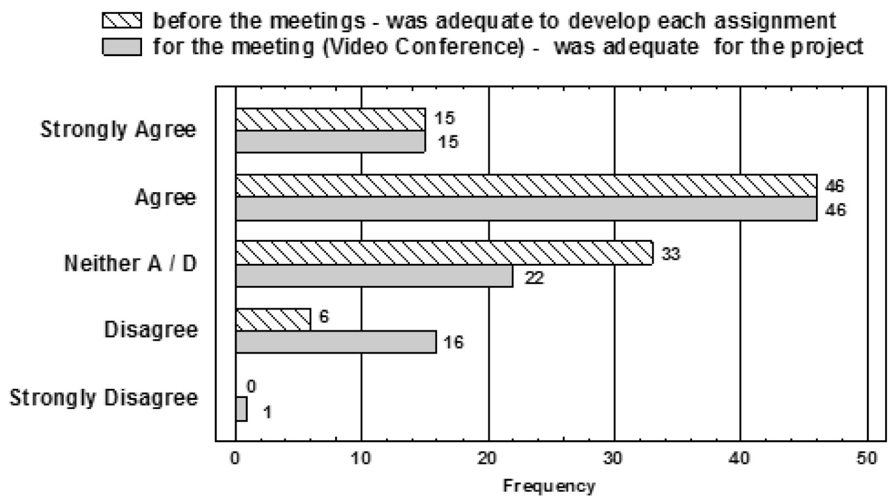


Fig. 5. Amount of time provided for the project before and during the meetings.

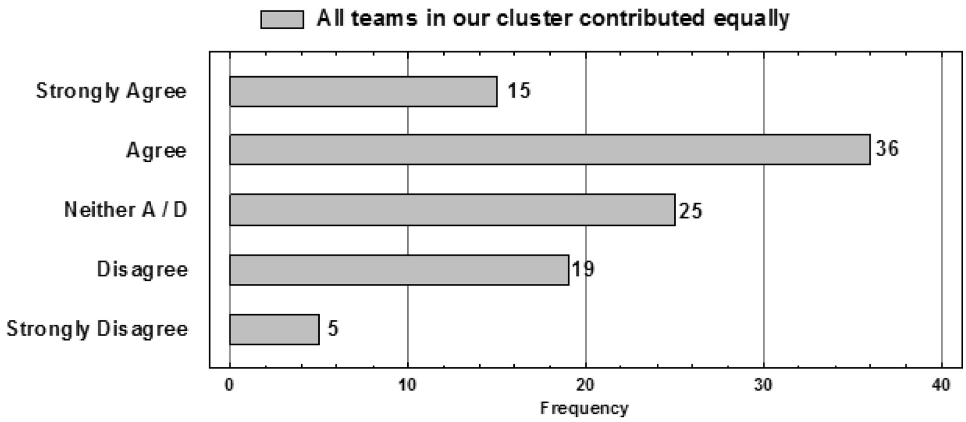


Fig. 6. Frequency in the contribution of the teams participating in the cluster equally.

collaborative project. However, 24 students said that the contribution was not equitable.

Figure 7 shows the opinion of the participants about the appropriateness of their personal willingness to work in the project and that of their partners. Most participants (77) agreed that their team was always prepared for meetings, participated actively and shared the information on time. Similarly, 53 students recognized that their international partners behaved the same way. However, 5 students acknowledged that their personal willingness was not appropriate for collaborative work. Also, 21 students considered that their international partners were unwilling to collaborative work.

Another aspect taken into consideration was the personal and technical information regarding the project shared during the collaborative experience. The first aspect tried to evaluate the importance of the personal interaction on the flow of information and if it was a relevant factor in building trust. The results show that, for most students (65%), the personal interaction was important to build trust and to facilitate communication (Fig. 8). In fact, 62% agree or strongly agree that personal interaction contributed to the flow of information for the project.

4.2 Preferred communication tools and type of shared information

The means used by the students for their interactions with their international partners as well as the intensity of their use were evaluated. As it can be seen in Fig. 9(a), the survey revealed that most participants preferred Audio-Video Conference (A-VC) (93), Google docs/drive (80), e-mail (78) and Facebook (75) as their most common way of communication. About intensity of use (Fig. 9 (b)), the communication media most intensely used (often or very often) were: Audio-Video Conference (A-VC) (62), Google docs/drive (43), e-mail (30), Facebook (43), and Online file share (Dropbox) (43).

The type of contact information shared with international partners was also evaluated. The results show that the contact information most frequently shared between team members was the email (41.09%) and Social Network (35.64%), as illustrated in Fig. 10.

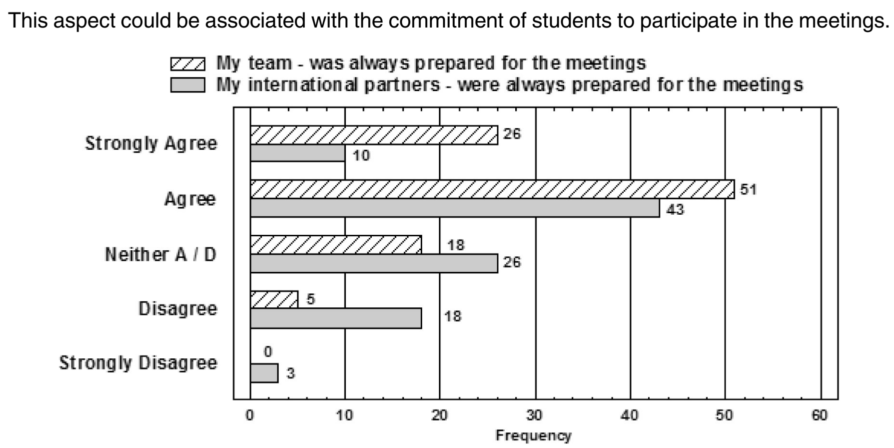


Fig. 7. Willingness of the teams to work collaboratively in the cluster.

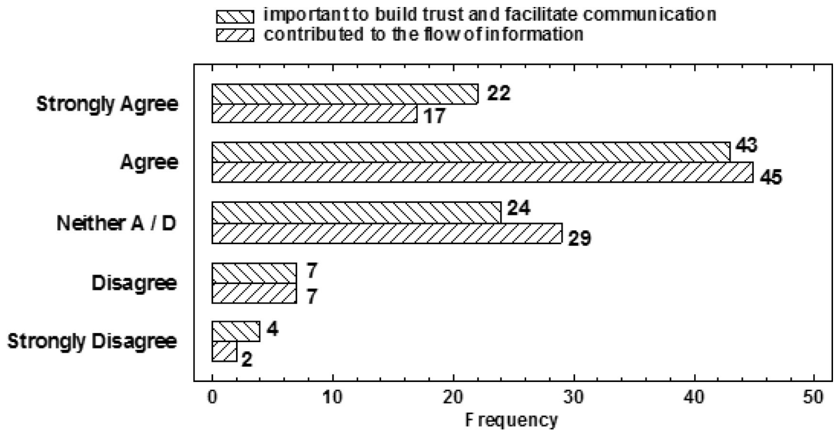
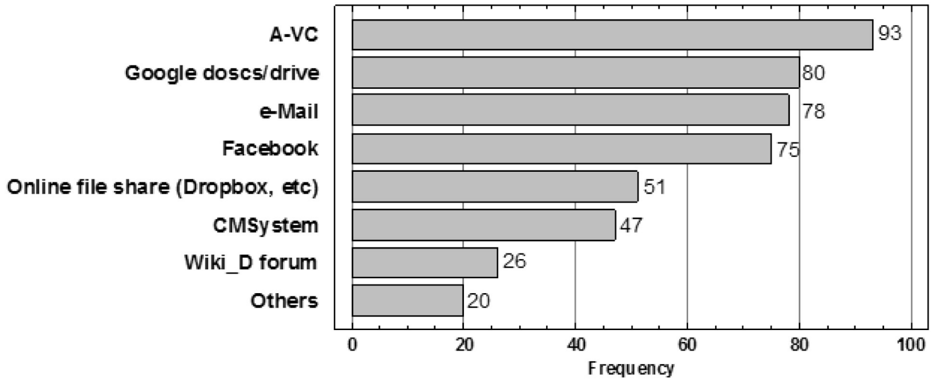


Fig. 8. Results about personal interaction.



(a)

Intensity of use	e-Mail	CMSystem	Google doscs/drive	Wiki_D forum	Online file share (Dropbox, etc)	Facebook	A-VC	Others
Very Often (75-100%)	9	6	21	2	7	23	37	1
Often (50-75%)	21	15	22	6	14	20	25	5
Regularly (25-50%)	24	15	15	9	14	23	16	4
Occasionally (1-25%)	24	11	22	9	16	9	15	10
Never (0%)	22	53	20	74	49	25	7	80

(b)

Fig. 9. Means of interaction and intensity of use: (a) communication media used; (b) intensity of use.

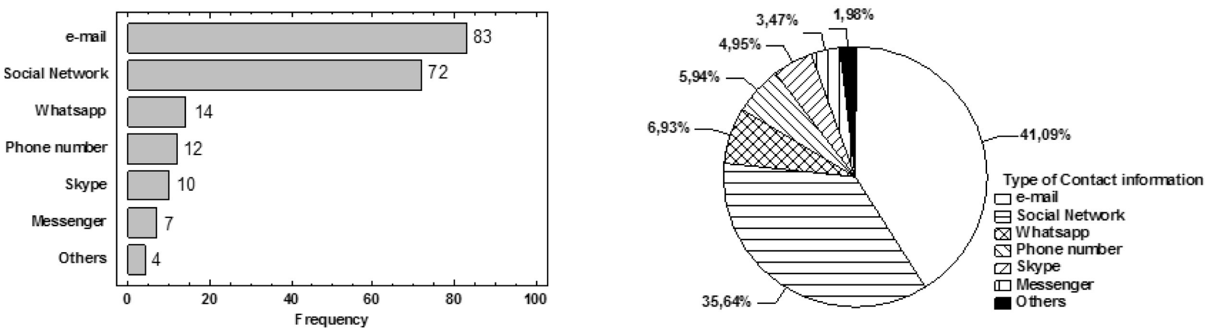


Fig. 10. Type of contact information shared with international partners.

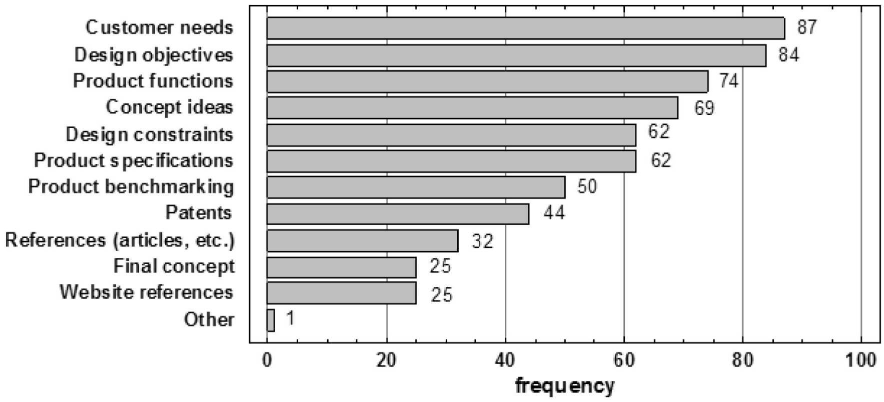


Fig. 11. Type of information related to the project shared with international partners.

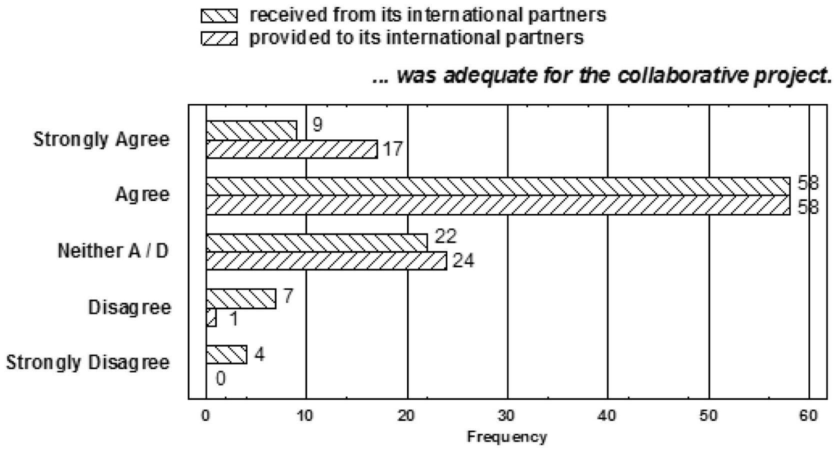


Fig. 12. Amount of shared information related to the project and its appropriateness.

4.3 Effects of the global collaboration in the project

An important aspect evaluated was the contribution of the collaborative experience in the project results. The information about the project that could be shared by the participating teams with their international partners is depicted in Fig. 11. As it can be seen, the survey showed that most participants shared customer needs (87), design objectives (84), product functions (74), concept ideas (69), design constraints (62) and product specifications (62).

Additionally, two important aspects about the information that was shared were evaluated: amount and quality of the information received and shared. About the amount of information received from international partners, the majority of participants (58) agreed that it was appropriate for the collaborative project. Regarding information shared, more than half of the students (58) believed that the information provided to their international partners was adequate for the project. In general, the majority of the students (75%) are of the opinion that the information provided was adequate for the collaborative project (Fig. 12).

Regarding the quality of the information received from international partners, more than half of the participants (61) agreed that it was appropriate for the collaborative project, and 24 students neither agree nor disagree on the quality of the information received for the project. Furthermore regarding the information received from the international partners, 51 of the participants agreed that it was valuable for the completion of the project, and 28 students neither agree nor disagree on the usefulness of the information received. Fig. 13 summarizes the results described before.

Finally, with respect of the effects that this collaborative experience had on people and on the performance of the design challenge, most of the participants agree that this experience motivated them to work on the project (61); helped their team to complete the project (50); helped them enhance their professional skills (66); improved their method to approach the product design challenge (67) and helped them to develop the design following a systematic approach to the problem (60). The results are shown in Fig. 14.

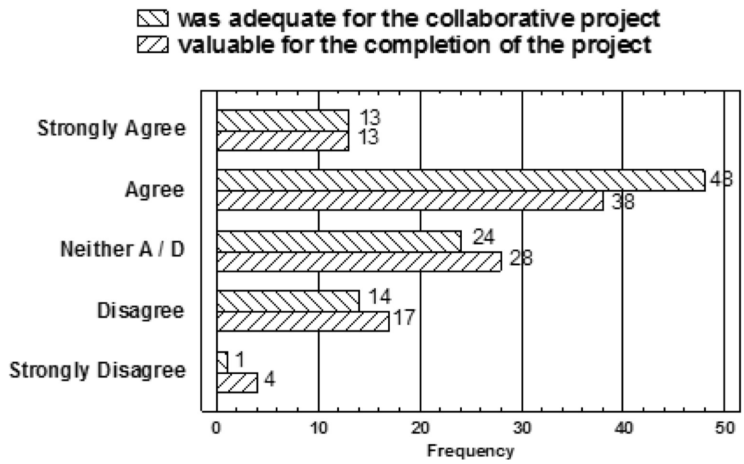


Fig. 13. Quality and usefulness of the information related to the project shared with international partners.

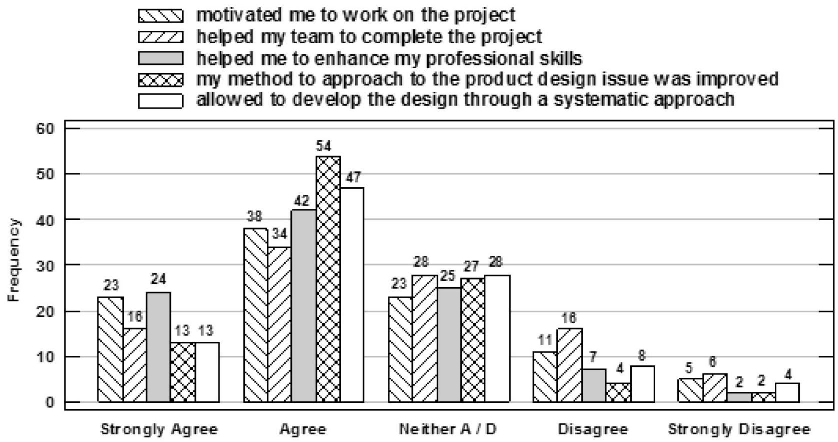


Fig. 14. Effect of this collaborative experience.

4.4 Exploratory principal component analysis

A principal component analysis with Varimax Rotation was used to determine the underlying or latent constructs of the scale. The correlation coefficients among the variables ranged from 0.078 to 0.741. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.853, which suggests that the data is very suitable for factor analysis, as the relationships between the variables were satisfactory. Bartlett's test of sphericity reached statistical significance (P = 0.000), which supported the factorability of the correlation matrix.

Four components were extracted from the exploratory sample (n = 100), the number of components was determined by size of the initial eigenvalues greater than 1.00. Table 1 shows the rotated component loadings of each item. Items in this study that had a 0.558 or higher loading were retained. A four-component solution was found to explain 68.47% of the total variance across all items.

The components found in this exploratory analysis represent constructs (or new variables) underlying the original variables allowing reduce the variables analyzed without losing the wealth of the information on the entire data (all variables).

Component 1 so called "*Connotation of Collaboration*" represents 20.29% of the variance. This construct expresses connotative meanings (connotation) of collaborative work (or collaboration). Thus, in the context of a collaborative project with teams composed of international peer associates in clusters, the meaning given to the concept of collaborative work, has the intentionality of: "Labor where participants receive and share information in appropriate quantity and quality, and the information is valuable for the task; where meetings should be prepared and where people actively participate and on time; labor where all participants contribute equally".

Component 2, "*Effectiveness of collaborative experience*" accounted for 18.42% of the total variance. This construct involves the usefulness of the collaborative activity in order to complete the project, to increase motivation for the project

Table 1. Results of exploratory principal component analysis (n = 100)

ITEMS		Component 1	Component 2	Component 3	Component 4	Name of component
1	The amount of information received from our international partners was adequate for the collaborative project	0.81				Connotation of collaboration
3	The quality of the information received from our international partners was adequate for the collaborative project	0.605				
7	The information received from our international partners was valuable for the completion of the project	0.666				
8	All teams in our cluster contributed equally to the collaborative project	0.645				
11	My international partners were always prepared for the meetings, participated actively and shared the information on time	0.738				
13	This collaborative experience motivated me to work on the project		0.594			Effectiveness of collaborative experience
14	This collaborative experience helped my team to complete the project		0.573			
15	My scholar experience (know-how) was adequate to approach to this collaborative experience		0.702			
16	My method to approach to the product design issue was improved by this collaborative experience		0.768			
17	The collaborative activity has permitted to develop the design by means of a systematic approach to the problem		0.788			
4	Personal interaction was important to build trust and facilitate communication in the multinational collaborative project			0.756		Social interaction
5	Personal interaction contributed to the flow of information for the multinational collaborative project			0.787		
18	This collaborative experience helped me to enhance my professional skills			0.673		
2	The amount of information we provided for our international partners was adequate for the collaborative project				0.755	Willingness to collaborate
9	The amount of time provided before the meetings was adequate to develop each assignment for the collaborative project				0.668	
10	My team was always prepared for the meetings, participated actively and shared the information on time				0.755	
12	The amount of time provided for the meeting (Videoconference) was adequate for the collaborative project				0.558	
EIGENVALUE		3.450	3.132	2.661	2.398	
PERCENT TOTAL VARIANCE		20.291	18.424	15.652	14.107	

work, to use the previous know-how and to improve skills.

Component 3, "*Social interaction*" accounted for 15.65% of the total variance. This component relates to the importance of building trust, the contribution it has to the flow of information and to the improvement of professional skills.

Component 4, "*Willingness to collaborate*" accounted for 14.11% of the total variance. This dimension involves connotative meanings to both personal and team attitude to work together in a collaborative way. This alludes to deliver to their international partners the right amount of information and to spend enough time to develop each assignment. It also includes the collective attitude of the team to prepare the meetings and to participate actively and on a timely manner in the project activities.

In accordance with this analysis, as shown (Fig. 15), the evaluation of collaborative experience is a multi-dimensional construct involving the connotation of collaboration, the effectiveness of collaborative experience, the social interaction, and the willingness to collaborate.

4.5 *Internal consistency reliability*

Reliability analyses showed good internal consistency for the instrument (n = 100). Overall scale internal consistency of alpha was 0.914, and the Cronbach's alpha for the four constructs are shown in Table 2.

4.6 *Limitations of the work*

A limitation of the current study was the nature of the assessment instrument used. The survey does

Fig. 15. Multidimensional assessment model of collaborative experience.

Table 2. Results of internal consistency of components

Name of component	Cronbach's alpha
Connotation of collaboration	0.836
Effectiveness of collaborative experience	0.874
Social interaction	0.807
Willingness to collaborate	0.739

not provide evidence of the cause of the interactions among the students. The study took place during an in-class project that was structured to provide the virtual space and time for communications and to promote the use of other tools to maintain that communication; however, the results from the survey do not allow to conclude which is the origin of student's motivation (internal or external) for their interaction with the international partners during the project. Additionally, it does not permit to determine the influence of the type of project in the methods of communication used. These two variables will be considered in a future work to complement this study and better understand the nature of the interaction and the overall impact in the development of the project.

5. Conclusions

As the goal of this study was to use the evaluation of the collaborative design project as learning tool, an "ad-hoc" assessment tool which considered questions grouped into five categories was developed and implemented. The evidence for the validity and reliability of the instrument which was developed for assessing the collaborative experience (section III) was supported by the use of exploratory factor analysis. A sample of 100 first and second year engineering students participating in the collaborative project was used.

The multidimensional assessment model proposed allows concluding that the "connotation of collaboration" could be considered as the most crucial dimension of collaborative experience. The hypothesis to be tested in future works would be that "the effectiveness or success of these experiences of collaborative learning depends largely on that participants adhere to the same connotation of collaborative work"; in other words, comply with those connotative meanings that call for the person a certain type of behavior when undertakes a collaborative experience.

From the results of the survey we can conclude that the proposed multinational collaborative product design is very useful for students. Within the answers respondents acknowledged that this type of project not only helped them develop skills for teamwork and effective communication with its international partners, but also to learn in a hands-on way about product design concepts. The overall collaborative experience motivated students to work on the project and be ready to share information with their international partners, which helped them to complete the assignment. Additionally, although not mentioned directly, it is inferred that the collaborative experience itself improved the methodology that students followed to face their design challenge.

Another interesting conclusion was the importance of face-to-face communication (video conference) and the use of email interactions with international partners, since those were the means of communication more used by students. It was interesting to notice the generalized use of Google docs and drive to exchange data instead of commercial applications such as Dropbox. The importance of using social networks to keep a more fluid, less structured and constant interaction between partners was also validated.

The results about the use of the ICT tools during the collaborative experience could lead to improve either them adaptability to the application field or the definition of new tools more tailored on the modern forms of communication and work sharing.

In fact the preference of Google's tools versus tools as Dropbox may be seen, not only regards the capacity of share files, but also with respect the possibility to operate modification in real time on the same file by more than one user.

It is interesting to point that the communication by means of email is still preferred even though social and more user friendly tools are today available. This could be justified by observing the kind of interaction and of information interchange required in the design field: more a long term.

The last observation regards the kind of information shared. They are referred to the early phases of the design work, when the design idea is less structured. Is it possible to conclude that the collaborative environment is more interesting and useful, in the design field, for the initial phases?

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