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Cross Cultural Issues on Globally Dispersed Design Team Performance: The PACE Project Experiences*

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Virtual collaborative engineering and design in a flat world relies upon the ability of distributed teams to perform as an integrated unit. Present research analyses how geographical dispersion and cross-cultural issues influence team performance when working under a collaborative engineering strategy. Its main contribution is to establish a common set of effective design practices for practitioners of design involved in new product development. Educators and students from Tecnologico de Monterrey in México, Virginia Tech & Howard University in the USA, Darmstadt University in Germany and Shanghai Jiao Tong University in China conducted this work. These universities are collaborating in the 'Partners for the Advancement of Collaborative Engineering Education' programme (PACE). The results come from design teams at ITESM and reflect a semester's worth of work. The students were enrolled in the senior year of the mechanical and industrial design engineering programmes and had previous experience related to the use of communication tools and CAD systems. The Nominal Group Technique (NGT) was applied to obtain multiple inputs from all persons involved in the project.

Keywords: cross-cultural issues; nominal group technique; collaborative engineering; collaborative design; globally dispersed design teams

INTRODUCTION

AN EMERGING CHALLENGE in global engineering is to focus on the cultural perspective of collaborative engineering. Knowledge sharing, collaborative knowledge creation, shared understanding and organizational learning are important elements for value creation and successful collaboration. However, several challenges and unsolved problems are foreseen in this area from the industrial perspective [1], including technical, social, organizational, cultural and economic aspects [2, 3, 4, 5].

Collaborative engineering is by definition a social process that requires communication and interaction among all team members. Additionally, collaborative design often relies upon the ability of distributed teams to communicate the main objectives of the project, to share a common vision of the design task and to understand the process and roles of each member on the team. Negotiation and bargaining are essential in this process. It is important to provide tools and methods so that also geographically distributed design teams are given the opportunity to engage in such social interactions. [3, 6, 7, 8]

This paper presents part of an ongoing research project in the context of PACE [1]. Currently educators and students from Tecnológico de Monterrey in México, Virginia Tech & Howard University in USA, Darmstadt University in Germany and Shanghai Jiao Tong University in China are participating in this project.

An intention of this work is to establish a common set of effective cross-cultural design practices for successful new product development similar to those in [9, 14]. Surveys conducted on participant students provided an overview of the main communication inhibitors, as perceived by them. In a similar manner to [9] the report presented here contributes to the characterization of projects involving geographically dispersed teams in addition to different backgrounds regarding work culture, language and time zone. The multidisciplinary and transnational nature of this project sets a framework where the use of collaborative and internet-based software is a requirement for the successful conclusion of the project [9, 10]. However, the focus of this paper is not to report on virtual tools designed to support the process, such as those reported previously by Bauer, *et al.* [11], Hashemi, *et al.* [12], and Kurt, *et al.* [13].

The research reported here was conducted by geographically dispersed and cross-cultural

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student teams and reflects a semester's worth of work. Team members from Tecnológico de Monterrey were enrolled in their senior year of the mechanical or industrial design engineering programmes. Students from the USA, China and Germany were enrolled either in undergraduate or graduate programmes. They all worked collaboratively on the development of an automobile, and in this case, used Teamcenter® as the PLM system and NX as the CAD/CAM platform, both provided by Siemens PLM Software [15].

THE PACE PROGRAMME EXPERIENCE

The PACE initiative (Partners for the Advancement of Collaborative Engineering Education) was formed in 1999 by EDS, General Motors and Sun Microsystems. Its goal is to create good technological conditions for teaching and research, at strategically selected academic institutions worldwide. The programme focuses on automotive design using Product Lifecycle Management (PLM). PACE is an integrated and parametric approach to all aspects of a product's life cycle from its design conception, through its manufacture, marketing, distribution and maintenance, finally into recycling and disposal, paying special attention to collaborative engineering as one of the core technologies for success [1, 2].

PACE industrial partners provide the participating academic institutions with state-of-the-art hardware and software for CAD/CAM/CAE and PLM [1, 3, 4]. According to the fact sheet (http://www.pacepartners.org/source/pacefacts.pdf) available at the PACE website [1], the programme reports more than US$7.3 billion dollars-worth of contributions of hardware and software tools to institutions.

Currently, the PACE programme is focused on:

- Requirements and planning (concept development).
- Styling (conceptualization).
- Product engineering (detailed design).
- Simulation (validation, optimization).
- Manufacturing engineering (tooling, machining, 3D plant layout).
- Managed development environment (product data management, supply chain management, digital collaboration).

PACE creates opportunities for research as well as curriculum and course development. It also fosters collaboration between its academic and industrial partners. The work presented in this paper is an example of such collaboration.

OBJECTIVES AND METHODOLOGY

Our main objective was to analyse the interaction among the students working in a geographically distributed collaborative engineering design team, hence to determine the main factors and cross-cultural issues that affect their performance. Once the communication inhibitors due to cultural differences were detected, a series of best practices could be proposed to overcome them.

A two-phase research approach was adopted; a first phase, based on a Nominal Group Technique (NGT) [16], was used to create a reference frame of the main factors and cross- cultural issues that diminished collaborative performance in the geographically distributed design teams These results where used, in a second phase, to design a Delphi questionnaire [17] which, at a later stage of the analysis, captured the perceptions of all international students.

The NGT group activity consisted of three consecutive question sets. The technique was used as an alternative to a structured variation of the small group discussion method. The process prevents the domination of discussion by a single person or group of persons, and encourages the more passive members of the team to contribute meaningful ideas. The overall objective of the NGT phase was to present the group ideas as a set of prioritized solutions or recommendations.

The steps for the NGT group activity were:

- The 12 Mexican members from different design teams were divided into groups of three or four members, and were seated around a table.
- An open-ended question was asked.
- Each individual member was asked to spend several minutes analysing and writing all his/her ideas to maximize the individual creative potential.
- The group then collected the ideas by sharing them in round-robin fashion (one response per person each time), while all were written on a flipchart. No criticism was allowed, but clarification in response to questions was encouraged.
- Each member evaluated the ideas and anonymously voted for the best ones.
- A group report was prepared, ranking the ideas according to the score generated.
- All ideas were classified into categories derived from Hofstede's work [8], namely: technical, social, organizational and economical. These types of categories were also applied in similar research by Verdour [16] and Madu [17]. However, due to simplicity, this work has consolidated organizational and economic issues into one category.

The second phase, the preparation of a Delphi questionnaire for all students in the design team, was developed based on the resulting issues of the NGT stage. All Delphi questions were derived, by the authors, and classified again in accordance to the Hofstede categories.

The resulting questionnaire was answered by all students in the team and the results analysed and classified to reveal the findings.

RESULTS OF THE NGT AND DELPHI EXERCISES

During the first phase of this work, as noted in the previous section, the following three open questions were used during the NGT group activities:

Q1: What are the main factors that inhibited the success of this engineering design team?
Q2: What are the main desired characteristics of the communication within this team design experience?
Q3: What are the action/activities needed to obtain the desired characteristics of the intra-team communication of this geographically distributed design team?

Tables 1 and 2 present the detected inhibitors for success of the engineering design teams (Q1). The ideas were grouped according to the categories: technical, social and organizational. In some cases, several categories applied for a specific inhibitor; when this occurred the issue was labelled as a cross-category. This organization of information allowed an easier observation of strong or weak interactions between the established categories.

Tables 1 and 2 also show that the organizational category aspects represent a great opportunity for

Table 1. Single-category related inhibitor ideas for Q1

What are the main factors that inhibited the success of this engineering design team?		
Social	Organizational	Technical
When team members try to locate a student at another university they find out ,that in many cases the pronunciation of the names of that partner is incorrect due to different languages and accents.	The local time change (like summer and winter times) has to be considered at the time courses are being proposed & scheduled. It is recommended to use a reference time.	Bad use of the videoconferencing system when several microphones are in use. Sometimes a team cannot listen to the others and this team has not the prompt possibility of knowing this. Only some videoconferencing systems use a color sign on the system screen that indicates this situation.
Participants are not fluent in English or do not understand other local accents.	Sometimes the team members are not aware of the quality and quantity of the time of their partners' dedication to the project.	Sometimes drawings files that are stored in the Teamcenter PLM system are not complete, or need plug-ins to be opened.
	Lack of training on the required software.	Different computer/equipment speed connections between universities.
	Lack of a well-established procedure to conduct videoconferencing meetings.	Lack of a document detailing the minimum set of software and hardware requirements for the design teams.
	Lack of information about "WHAT TO DO?"	Not all students had available computers at the time of the video conferences.

Table 2. Cross-category related inhibitor ideas for Q1

What are the main factors that inhibited the success of this engineering design team?		
Technical & Organizational	Social & Organizational	Technical, Organizational & Social
The incorrect use of microphones when a partner is not participating in the video conferencing group conversation.	Students cannot easily recognize their partners although photographs of all team members are available in the Teamcenter PLM system.	Difficulty in working under the collaborative scheme (personal performance).
The mute function should be used in automatic mode.	The presentation and identification of team partners are perceived like a very important issue.	Verbal communication interferences that occurs when Video Conferencing is taking place.
Confusing communication during videoconferencing.	Ages and academic background of team members are perceived as important issues for interaction.	
Communication often overlaps because of the lack of a communication protocol and poor role of a facilitator.	Students from different countries have different expectations about the results of the design project.	
File storage seems to be difficult to track due to the lack of a common storage and classification structure.	Difficulties in working across different time zones.	
	Lack of a leadership role definition.	
	Undefined "right" frequency of expected communication.	

improvement in terms of a successful virtual and geographically distributed design team. Although there are several categories, the opinion of many of the persons involved in this exercise was that the category that better reflects the cultural issues is the combination of social and organizational.

The second question Q2 was used to obtain the desired characteristics of a successful distributed design team performance. The result (Table 3) shows again that the organizational and social aspects reflect characteristics that, as perceived by the participants of the project, are closely related to cultural issues, indicating that all parts of the communication process are important to guarantee an acceptable team performance, especially the need for verification of shared understanding.

The third question was asked to obtain the main actions to follow for a successful distributed design team performance (Table 4).

In the combined 'social and organizational category' a visual component is proposed (drawings, sketches, schemes, tables, or others) as a way to improve communication in the virtual team. A well-established structure and organization of the project information in the 'Teamcenter web page' since the beginning of the virtual exercise is also required.

SURVEY ON COLLABORATIVE DISTRIBUTED ENVIRONMENTS

In the second phase, the Delphi method was applied and another survey was designed taking into account the ideas and results from first phase group activity. In this case, the survey was applied to all team members (not only the Mexican ones). Design team member composition included American, Chinese, German and Mexican participants of which 98 per cent were undergraduate students (Table 5).

Table 3. Single and cross category related characteristic ideas for Q2

What are the main desired characteristics of the communication within this team design experience?		
Organizational	Organizational & Social	Organizational, Social & Technical
Define meeting scheduling guidelines taking into account the different time zones of participants.	Improve computer-mediated tools to support non-verbal communication.	An easier and visual way to transmit ideas.
Clear information about objectives, aims, milestones, and other agenda related issues.	Define feedback or confirmation procedures to prevent misinterpretation issues due to different linguistic background of participants.	
Good planning of the use of software, hardware and physical spaces.		

Table 4. Single and cross category related action ideas for Q3

What are the action/activities needed to obtain the desired characteristics of the intra-team communication of this geographically distributed design team?		
Organizational	Organizational & Social	Organizational, Technical & Social
Allocate work session time for team meetings & agreements.	Improve the quantity and quality of information.	Confirm that ideas are well understood.
Create a good work plan.	Improve the structure and organization of the "Teamcenter web page".	All team members should have computer access during videoconferencing.
	The use of visual help (drawings, sketches, schemes, tables, and others) to ensure good communication.	
	Define an early work process plan or methodology.	

Table 5. Nationality & number of members on each design team

Nationality	TEAM 1 Buick Excelle	TEAM 2 Adam-Opel	TEAM 3 Buick	TEAM 4 Daewoo
Mexican (20%)	2	4	4	2
Chinese (20%)	4	5	4	5
USA (50%)	2	1	4	2
German (10%)				2*

* One German participant was a graduate student.

Questions were phrased considering all aspects of collaborative distributed environments identified during the NGT exercise. The questions were organized in twelve subgroups as follows:

1. Technical skills developed through this project.
   This subgroup provided feedback about the opinion about the Product Life Cycle Management software used in the project.
2. Compare this project to a non-virtual one.
   This subgroup captured the opinions of participants relating to their experiences in virtual design teams versus traditional ones.
3. Team work.
   This block of questions captured the evaluation about teamwork performance.
4. Team communication.
   This subgroup proposed a series of questions by which the communication technologies available to the project were judged.
5. Instant messaging.
   (Part of subgroup 4)
6. Videoconferencing.
   (Part of subgroup 4)
7. Teamcenter PLM System.
   (Part of subgroup 4)
8. Intercultural skills.
   This subgroup provided information about the intercultural issues that were observed during the project.
9. Conflict resolutions.
   These questions analysed the reasons for friction and procedures for conflict resolution.
10. English skills.
    This set of questions captured problems derived for varying levels of English proficiency amongst team members.
11. Equipment in the classroom.
    This set of questions captured problems derived for varying levels of resources associated with the classroom amongst team members.
12. Virtual teams in your future.
    This subgroup tried to capture the perception of value added for the students' future professional life.

In analysing Table 6 we can synthesize some important contributions of the virtual teams that were involved in this exercise. Following is a summary of those findings:

- The implementation of the Teamcenter PLM system was helpful for the project planning and progress organization.
- The project was a great opportunity for all team members to learn collaborative engineering design.
- Communication played a key role throughout the entire project. In virtual meetings, the teams had to respect other countries' time, holidays and language differences.
- Because English was the only language used to communicate, the teams faced some difficulties due to a wide variety of different accents and colloquialisms. Those difficulties were barriers to conveying messages and information. However, this miscommunication was lessened greatly by using instant messaging text tools available to the IP telephone tool used in the project (Skype software and other instant messaging tools were used).
- Students mentioned several times that the planning materials and schedule were practical and helpful in understanding the true meaning of global collaborative engineering.
- Good communication skill within multicultural teams must be to learned, especially when technical terms are involved.
- Interpreting and comprehending others ideas and points of view, is highly influenced by cultural background.
- There is a need for proper scheduling, division of work and collaborative sessions design..
- The project was a good opportunity to develop design skills through the use of the NX CAD* software and effective use of media.
- Patience and slow, calm explanations are crucial when overcoming communication gaps.

Almost every student involved in the project perceived it as a good experience and this was reflected in how members felt about virtual teams in their future. One student's quote is typical of the overall degree of satisfaction with the project:

> The Global Collaborative Engineering Design course was a very interesting experience, and could be applied in real international projects. It was very nice to work with students of many different parts of the World. From our new point of view the World got a lot smaller.

CONCLUSIONS

Although the number of students involved in this research is limited and results cannot be generalized, important information was obtained as follows:

- It is very difficult to structure cross-cultural issues as each individual finally acts differently.
- Virtual team members can overcome culture-related difficulties in a tolerant environment. Team members can adapt their behaviour in both spoken and written communication as well as allowing for social and organization context differences, as well as for time zone mismatches.
- If there is commitment to the common task, cultural differences are not an impossible obstacle to overcome.
- Collaboration tools such as desktop sharing applications for conferencing are useful resource, due their capacity to aid the expression and explanation of complex matters.

* Unigraphics NX is the Simulation Module of this CAD-PLM software.

Table 6. Delphi survey results*

1. Technical skills developed through this project	Agree	2	3	4	Disagree
I had experience with the NX CAD system before this project	10	20	20		50
I have improved my skills in the NX CAD system in this project	10	20	40	10	20
2. Compare this project to a non-virtual one	**Agree**	**2**	**3**	**4**	**Disagree**
This project is more interesting to you than a non-virtual project	30	50	10	10	
It was difficult to identify your team mates at the beginning	10	50	10	30	
You felt It was more difficult to trust the team mates you have only met by video conference		25	40	25	10
Do you spend more time in a virtual team project than in a non-virtual one?	15	30	20	5	30
You achieve as good work relationship with your virtual team as with you local team	10	65		25	
3. Team work	**Agree**	**2**	**3**	**4**	**Disagree**
My team members lack commitment			5	90	5
My team mates are too harsh		15	30	15	40
Team members are not aware of the quality and quantity of the time their partners are dedicating to the project, thus making it difficult to follow the work plan of your team			75	5	20
You feel you achieve more with your international team than with only a local team	20	40	10	30	
Ages and academic backgrounds of team members are important issues at the interaction level	20		10	60	10
We had a plan to complete the whole project	20	35	35	10	
Your activities in this project are defined and limited		30	60	10	
4. Team communication					
What is your preferred collaboration medium for technical discussion?	Voice IP 10	E-mail	Inst. Msg. 45	Video Conf. 20	Face to Face 25
When you have a meeting, you already have a plan for that meeting	Yes 15	Mostly planed 85	Objectives only	Some thoughts	No plan at all
5. Team work communication by instant messaging	**Agree**	**2**	**3**	**4**	**Disagree**
You host meetings through this technology	80		5		15
You communicate with your teammates to schedule a meeting with this technology	70		5	5	20
6. Team work communication by videoconferencing	**Agree**	**2**	**3**	**4**	**Disagree**
You host meetings using the videoconference room	60	10	30		
You had some problems deciding when to meet (time zone)		30	45	20	5
I feel missing a video conference meeting is far worse than a face to face meeting	15	25	50		10
7. Team work communication via the Teamcenter PLM system	**Agree**	**2**	**3**	**4**	**Disagree**
You host meetings using Teamcenter	30			5	65
You use Teamcenter functionality for sharing applications	70	5		20	5
You use Teamcenter to communicate with your team	50	40	5	5	
You use the sharing application functionality in combination with instant messaging or voice IP	70	10	5	15	
8. Intercultural skills	**Agree**	**2**	**3**	**4**	**Disagree**
You would like to collaborate in a virtual team again.	90			10	
You feel it was easy to work with other cultures	40	35	25		
I have talked to my team mates about other subjects not related to the project	80		5	15	
I am interested in short culture summaries for a better understanding other team members	60	25		15	
9. Conflict resolution	**Agree**	**2**	**3**	**4**	**Disagree**
I prefer a fast decision which may not satisfy everyone or a slow decision everyone approves of	20	40	35		5
I sometimes use my own language during a virtual meeting/ although some of the other participants can't understand me		20			80
I am bothered by others using their own languages if I don't understand them		40	30	5	25
I rather have a direct criticism if that may solve the conflict with my team	50	35	15		
My other team mates should be aware of my culture in order to have good communication	30	35	35		
My team has prejudices that inhibit communication.			10	45	45
Cross cultural teams should avoid slang/colloquialism/jargon/acronyms	30	60		5	5
10. English skills	**Agree**	**2**	**3**	**4**	**Disagree**
I have difficulties in understanding (English) of other participants		40	25	25	10
I have excellent English communication skills	50	30		20	
11. Equipment in the classroom	**Agree**	**2**	**3**	**4**	**Disagree**
I have access to a videoconference room	75	15		10	
I have access to workstations running Siemens PLM and CAD software	90			10	
I have access to Internet	90			10	
12. Virtual teams in your future	**Agree**	**2**	**3**	**4**	**Disagree**
This project gives you extra curriculum value	90			10	
You will collaborate in a virtual team in you future job if you had a chance	85	5			5
You will propose a virtual team in your future job if you consider it might solve a problem.	90			10	

* The results are presented as percentages; not all members answered the survey; rounded and adjusted numbers are used.

- Face-to-face videoconference meetings proved to be essential for effective team building.
- Successful forming of an integrated, powerful and compelling team is the key to winning cross-cultural design teams. Team integration required acceptance and understanding of cultural differences within the team while focusing on one common objective.
- Instant messaging software helps teams reduce language difficulties. Normally, a team member who has English as his first language could think that this technology reduces the quality of communication, but for people with English as a second language it is very useful, because it allows team members to assure the content of the messages they are receiving or delivering.

Further research is necessary to isolate cultural effects from those that can be due to the inexperience in teamwork, as well as the use of communication software and tools. The next step in this research should focus on the creation of a framework of behavioural adaptations to help streamline cross-cultural virtual team formation and improve team interactions and performance.

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