Assessing interactions among students geographically disperse during multinational design projects

Dr. Ivan E. Esparragoza, Pennsylvania State University, Media

Ivan E. Esparragoza is an Associate Professor of Engineering at Penn State. His interests are in engineering design education, innovative design, global design, and global engineering education. He has introduced multinational design projects in a freshman introductory engineering design course in collaboration with institutions in Latin America and the Caribbean as part of his effort to contribute to the formation of world class engineers for the Americas. He is actively involved in the International Division of the American Society for Engineering Education and in the Latin American and Caribbean Consortium of Engineering Institution (LACCEI) as Vice-President for Meetings and in the International Federation of Engineering education Societies (IFEES) as VP for the Americas and First VP.

Dr. Sheila Katherine Lascano Farak, Universidad Técnica Federico Santa María

Sheila Lascano is an Assistant Professor of Mechanical Engineering at Universidad Técnica Federico Santa María in Santiago, Chile. Her research interests are in Biomaterials and Design. She is currently working in a Project to assess global competencies in multinational collaborative design projects.

Prof. Jared Roberto Ocampo, Universidad Tecnológica Centroamericana

Jared R. Ocampo is currently a researcher of the Faculty of Engineering at Universidad Tecnológica Centroamericana (UNITEC) campus of San Pedro Sula and previously worked as Academic Head of Engineering, Mechatronics Engineering Coordinator and as an undergraduate and graduate professor. He also works as a private consultant in the areas of industrial automation and industrial process simulation. Because of his experience with software and hardware he also works as a representative for Flexsim Simulation Software and National Instruments.

He has a degree in Mechanical Engineering and an MS also in Mechanical Engineering from Brigham Young University (USA) and is currently working on his dissertation to complete his PhD in Technology Management at the Polytechnic University of Madrid (Spain).

Prof. roberto vigano', Politecnico di Milano

Roberto Viganò graduated in Mechanical Engineering at the Politecnico di Milano, then he achieved his Ph.D. in Applied Mechanics in the same University. He is Associate Professor in Methods and Tools for Industrial Design at the School of Industrial Engineering at the Politecnico di Milano. His research activity is mainly dedicated to the fields of Computer Aided Design, Virtual Simulation and Industrial Engineering Design Methods.

Jorge W. Duque-Rivera Duque-Rivera, Escuela Superior Politécnica del Litoral

Professor and Program Coordinator, Mechanical Engineering Program. Faculty of Mechanical and Production Sciences Engineering, ESPOL. Guayaquil, Ecuador. Teaches Thermodynamics, Heat Transfer, Energy Consersion Systems, Energy Conservation and Introduction to Mechanical Engineering. Leads the international and national accreditation efforts of the ME Program of ESPOL.

Prof. Carlos A. Rodriguez, EAFIT University

Mechanical Engineer, EAFIT University. Medellin Colombia. Msc in Engineering, EAFIT University, Medellin, Colombia. Professor, Production Engineering Department, EAFIT University, Medellin, Colombia.

Assessing interactions among students geographically dispersed during multinational design projects

The new business model and global operations of many enterprises have brought new challenges for engineers working in multinational companies. These new trends and the need of educating world-class engineers with global competencies have opened opportunities for new educational models to expose students to international experiences to start developing those capabilities. One pedagogical activity used to promote global competencies is the participation of students in multinational design projects, which 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. Consequently, a collaborative network of institutions from the Americas and Italy has developed and executed collaborative multinational design projects as part of academic experiences for their students. 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. 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.

Introduction

It is evident that globalization is facilitating the access to human capital around the world. Advancements in information technology have enabled the communication and interaction needed to create teams formed with people who possess different, and complementary skills and that are located in different parts of the world. 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[1].

According to Davidow & Malone[2], advances in the information and communication technology (ICT) along with the development of team-based structures as part of the organization design have facilitated the creation of these globally distributed teams (also known as global virtual teams). A globally distributed collaboration takes place when two or more teams from different geographical locations work together to accomplish project goals[3]. These types of teams are becoming increasingly common in areas such as product development and information systems. However, even though there are obvious advantages of conforming and working in globally distributed teams, these types of teams also face several challenges in addition to the well-known communication issues resulting of their dispersed geographical locations. These teams face

differences in time zone, language, national traditions, values and norms of behavior[4]. Therefore, engineering students should have the learning opportunities and experiences that are necessary to develop those competencies which are required to work in such environments and be competitive in the global market.

Due to the need of preparing engineers with technical and professional skills to be competitive globally, the use of collaborative projects as a learning approach is becoming a valuable practice in the academia. This approach is based on the notion that in the corporate world the development of a product is an activity that requires various competencies and the collaboration among a diverse group of individuals. Due to globalization, these groups can be found in different parts of the world. Thus, the use of global collaborative or geographically dispersed projects in the academia is a problem-based learning (PBL) approach in an international setting. In these projects, 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 enhance professional skills through the interaction with multinational teams while giving solution to a specific design problem.

Geographically dispersed projects as a PBL approach

The new economic model and the way corporates are doing business around the world require engineers to be prepared to work in teams geographically disperse around the world. This brings the challenge of understanding different languages and cultures while working in multinational teams. Additionally, engineers should know how to use proper communication technologies, solve problems and present their solutions in global environments[5]. This reality has been recognized by the industry, academia and accreditation agencies. Consequently, engineering programs should provide their students, as early as possible, with academic and international experiences to promote the development of professional skills as part of their training.

One academic approach to foster professional skills and, at the same time, expose the students to an international experience is the use of global design projects. In these projects students work cooperatively with teams that are geographically dispersed to solve an engineering problem[6]. This approach uses the project-based learning (PBL) technique combined with a multinational experience. PBL is based on the idea that a problem or a question, guide learning activities for the construction of a particular device in a real context[7]. In this process, students seek solutions to open problems by formulating research questions, plan design, collection, analysis and integration of information, explanations and building models, and creating artifacts or products of their understanding. Students also have the opportunity to control the learning process, making decisions about the pace, sequence and content of learning, and evaluating the results of their efforts and their learning strategies. 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)[8], which are enriched by the international collaboration among the students in the global design projects.

Using project-based environments introduces cognitively complex tasks in the process of learning, experimentation, self-direction and high-level metacognitive control. These environments are necessary for students to effectively undertake PBL[9,10,11]. However, the strength of PBL appears to lie in giving students the opportunity and motivation to work in a more meaningful way (personally) to a "solution". Several researchers observed deficiencies in the performance of students in the various activities of PBL, referring to self-directed learning skills and metacognitive knowledge[12,13,14]. Therefore, strengthening metacognitive skills and reflection in students is essential in such innovative learning environments to help them to adopt strategies and reasoning processes that enable them to define, plan and self-monitor their thinking and learning style. In this sense, metacognitive and reflective skills of students better rely on social learning environments[13]. Social interaction promotes the development of cognitive structures of individuals, when individuals reconcile the differences between their own ideas and the ideas of others, and when they ask questions and explain their reasoning for solutions[15,16,17]. Research studies suggest that teamwork provides opportunities for the development of cognitive structures of members and cultivate positive attitudes and stronger motivation toward the task, compared with individual work[18]. However, research on collaborative learning has shown that its effectiveness depends on the richness and intensity of interactions among group members[19].

PBL and global design projects offer opportunities for students to develop global competencies; however, it can be argue that the effectiveness of this approach and the success of this experience depend highly on the interaction of the multinational teams during the project. Under this premise, the aim of this work is to develop an assessment tool to evaluate the interactions of teams in a global design project with the specific objectives to determine the value of social and technical interactions in the flow of the project and in the completion of the project.

Collaborative project

Collaborative projects are common practices in many industries nowadays and they are becoming also a valuable learning tool in the academia. The emphasis for collaborative projects developed in academic settings is in the project process. In this environment both the final solution and the learning process are important[20]. On the other hand, in the corporate environment a feasible and viable solution is sought according to a financial investment. In this case, enterprises focused completely on tangible results might ignored that the social and technical achievements of their professionals during the collaboration experience are, although no tangible, part of the corporate gains[21]. Therefore, the process in collaborative projects is important independent of the type of environment where the project is being executed. Social and technical interactions among team members are critical in a collaborative environment, especially in a global scope, since effective interactions nurture building trust, despite cultural differences, and facilitate the flow of information during the execution of the project.

There are different types of collaborative projects that can be adopted as described by Jenkinson et al[22]. The complexity and resources that are necessary to implement them vary from simple and low cost projects to more complex and expensive ones. Usually, the simple and less expensive project consists of a case study where the students just report the final result to their international partners. In this type of project, minimum interaction is required and is usually a one-time, in class experience. In contrast, the international projects known as “integrated teams” require further interaction between students, since they work together in multinational teams. These projects are usually long term and demand high level of commitment from students and staff.

The project structure selected for the multinational collaboration reported in this paper is the parallel design project, in which the teams in each country work independently on the same design proposal but they are required to share information and discuss ideas with their international partners to enrich the final solution. The development of the project following a design process is shown in Fig. 1 where local and international activities are identified.

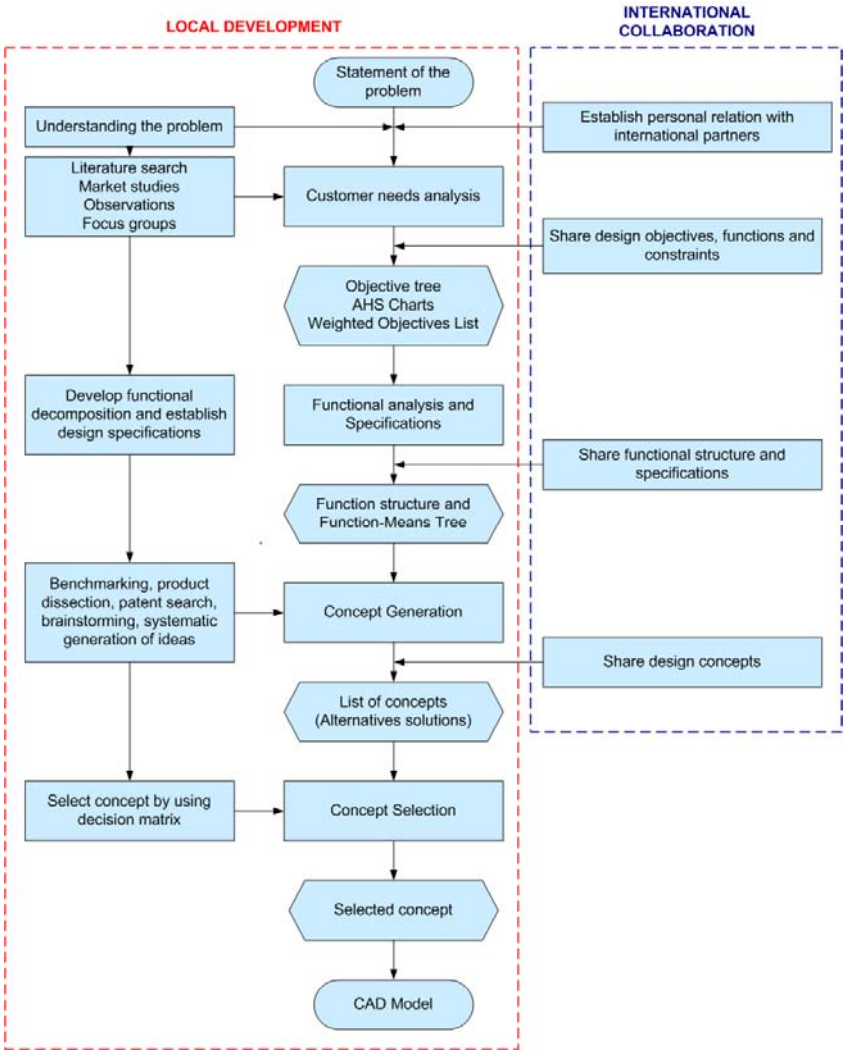

Figure 1 Design process for the collaborative project

The collaborative project takes place during the academic semester and it last for eight weeks. During this time they are required to have at least four audio-video conferences scheduled in the project, exchange ideas, and to interact with their partners using other electronic means as decided by the teams. Formal and informal tools for interaction are allowed and encouraged. Formal tools are those considered fundamental for managing the project and for creating a professional environment, while informal tools are those considered important to build personal relationship among the participants and overcome the difficulties of working with partners geographically disperse with no physical interaction.

The collaborative network is formed creating clusters where two to five multinational teams are grouped to work cooperatively. Fig. 2 shows a typical collaborative network formed by six clusters and 28 teams from six different countries.

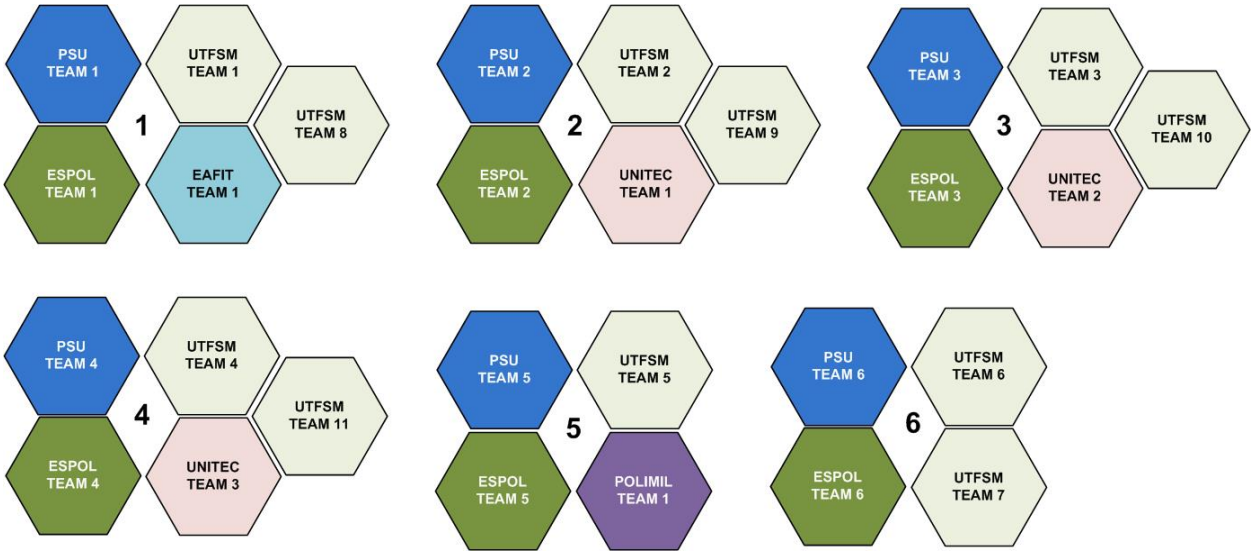

Figure 2 Collaborative network for multinational design projects

Since the interaction among the international teams is the issue under study on this work, specific instructions were given to the students to keep and report the interaction with other teams in the cluster. The set of activities and tasks for this purpose are summarized on Table 1. From this table can be seen that students have specific tasks to complete before, during, and after the interaction with the international peers. These tasks guide the students during the execution of the project. Additionally, they foster interaction among students which are geographically dispersed which is a very important goal of this practice and the main topic of this study.

Table 1 Reporting interaction for collaborative project

Activity	Tasks	Deliverable
AV-1 Conference	During the meeting: Establish personal relations. • Exchange e-mail contacts • Determine the tools to be used to exchange information (Google docs, Dropbox, etc.)	After the meeting: Written report summarizing: • Who attended the AV-1 conference • Information collected from international partners • Tools to be used in the project.
Advance Report I	Define: 1. Initial attribute list 2. Categorize the attribute list into objectives, constraints and functions 3. Categorize the objectives into sets by grouping them by similarity 4. Hierarchical objective list 5. Augmented hierarchal list	Written report including the five (5) tasks listed for this activity
AV-2 Conference	During the meeting: Share with your international partners your Advance Report I.	During the meeting Share the advance report on your meeting room on Adobe Connect (put the report in Powerpoint of PDF to be able to share it)
	After the meeting: Report interaction	After the meeting: Written report summarizing: • Who attended the AV-2 conference • Information collected from international partners
Advance Report II	Establish: 1. Product function o Function tree 2. System functionality o Black box model o Transparent box model 3. Design specifications	Written report including the three (3) tasks listed for this activity
AV-3 Conference	During the meeting: Share with your international partners your Advance Report II.	During the meeting Share the advance report on your meeting room on Adobe
	After the meeting: Report interaction	After the meeting: Written report summarizing: • Who attended the AV-3 conference • Information collected from international partners

Assessing student interaction in geographically dispersed projects

A big challenge of the geographically dispersed projects has been to create an effective interaction among the participating students, and to maintain the flow of information and students engagement in the project and in their learning process. It is believed that if during the collaborative project the social and technical interaction is effective, then the results of the project and the learning experience will be better. Therefore, this goal of this work related is to develop an assessment approach to monitor students' interaction in multinational collaborative projects. The main objectives of this approach 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.

The work by Potter and Balthazard[23] focuses on the assessment of virtual team interactions styles, and establishes two hypotheses relating the interaction styles with the prediction of objective measures and process measures of team performance. This work also summarizes the work of many researchers studying team interaction styles and the assessment of this practice in virtual environments. However, their work is limited to the analysis of constructive, passive and aggressive group interaction in the overall performance of the group.

In this work, the social and technical interaction between the teams in terms of frequency, quantity and quality are of interest to determine its impact in the flow of the collaboration and the overall development of the project. For this reason, the teams' multinational interaction domain is composed of two spaces as defined by Barron[24]: the content space (the problem to be solved) and the relational space (social interactions challenges and opportunities). In the technical space students discuss technical aspects of the project, share ideas and concepts and evaluate possible solutions. The social interaction is characterized by the exchange of personal information and the discussion of personal preferences and cultural information that will help to build the trust in the team which is one of the most challenging tasks in multinational teams.

The survey developed to evaluate the interaction in global collaborative project is summarized in Table 2. This survey was developed using a focus group composed by instructors participating in this project work based on the objectives of this work. Validity and reliability of this instrument will be established as data is collected in the multinational projects.

Table 2 Survey for interaction in global collaborative design projects

1. Gender	○ Male ○ Female
2. Location	○ Chile ○ Colombia ○ Ecuador ○ Honduras ○ Italy ○ US
3. How often did you interact with your international partners using any means of communication (AV conferences, e-mail, text message, wiki, discussion forum, shared files, etc.)?	○ Never (none) ○ Seldom (one to three) ○ Sometimes (three to five) ○ Often (five to ten) ○ Very often (more than ten)

4. How often did you attend the scheduled meetings (AV conferences and other meetings arranged by your group of collaborators)?	○ Always (100%) ○ Very often (80 – 99%) ○ Often (50 – 80%) ○ Sometimes (25 – 50%) ○ Seldom (1 – 25%) ○ Never (0%)
5. How many hours per week did you spend working with your international partners?	○ Zero ○ One to two hours ○ Two to three hours ○ Three to four hours ○ More than four
6. What were the means you used for your interaction with international partners (select all that apply)?	☐ Audio-Video conferences ☐ E-mail ☐ Course management system ☐ Google docs ☐ Wiki/Discussion forum ☐ Online file share (Dropbox, etc.) ☐ Social media (Facebook, etc.) ☐ Other (specify) _____
7. What was your main means of interaction?	○ Audio-Video conferences ○ E-mail ○ Course management system ○ Google docs ○ Wiki/Discussion forum ○ Online file share (Dropbox, etc.) ○ Social media (Facebook, etc.) ○ Other (specify) _____
8. What type of contact information did you share with your international partners (select all that apply)?	☐ Email ☐ Phone number ☐ Skype ☐ Messenger ☐ Whatsapp ☐ Social network (Facebook, etc.) ☐ Other (specify) _____
9. What type of information regarding the project did you share with your international partners (select all that apply)?	☐ Customer needs ☐ Design objectives ☐ Design constraints ☐ Product functions ☐ Product specifications ☐ Concept ideas ☐ Final concept ☐ Patents

	☐ Product benchmarking ☐ References (articles, books, reports) ☐ Website references ☐ Other (specify) _____					
(5) Strongly Agree, (4) Agree, (3) Neutral, (2) Disagree, (1) Strongly Disagree, (0) Not sure	5	4	3	2	1	0
10. The amount of information received from our international partners was adequate for the collaborative project	○	○	○	○	○	○
11. The amount of information we provided for our international partners was adequate for the collaborative project	○	○	○	○	○	○
12. The quality of the information received from our international partners was adequate for the collaborative project	○	○	○	○	○	○
13. Personal interaction was important to build trust and facilitate communication in the multinational collaborative project	○	○	○	○	○	○
14. Personal interaction contributed to the flow of information for the multinational collaborative project	○	○	○	○	○	○
15. Personal interaction was not adequate to maintain the flow of information for the multinational collaborative project	○	○	○	○	○	○
16. The information received from our international partners was valuable for the completion of the project	○	○	○	○	○	○
17. All teams in our cluster contributed equally to the collaborative project	○	○	○	○	○	○
18. My team was always prepared for the meetings, participated actively and shared the information on time	○	○	○	○	○	○
19. My international partners were always prepared for the meetings, participated actively and shared the information on time	○	○	○	○	○	○
20. This collaborative experience motivated me to work on the project	○	○	○	○	○	○
21. This collaborative experience helped my team to complete the project	○	○	○	○	○	○
22. The information received from our international partners contributed to the completion of our project ……	○ a lot ○ significantly ○ little ○ nothing					
23. Please list three things that you and/or your team did well during this collaborative experience:						
24. Please list three problems that you and/or your team had interacting with your internationals partners:						
25. If you were to repeat this experience again, please list a specific action that would help the interaction with international partners even better next time:						

As it can be seen, the instrument provides demographic details and information related to the type of communication tools used for the interaction, the frequency and duration of interactions, and the quality of these interactions in terms of the type of information exchanged among teams. The instrument also allows determining the perceived usefulness of the interactions among the teams to complete the design tasks due to the information received from international peers, and the motivation created by the experience of working with multinational teams.

Conclusions

The use of multinational design projects in engineering education has been identified as a novel approach to expose students to an international experience that allows them to start developing global competencies. However, the interaction among the teams geographically dispersed around the world has been identified as a critical issue for the success of this practice as it has been observed by the instructors after nine years having this experience in the classroom. Therefore, it is of major interest to understand the effectiveness of the interaction among the students working with international teams during the collaborative design and its impact in the final solution. Consequently, this work presents an assessment instrument that has been developed to evaluate the interaction among the students participating in a multinational collaborative design based on the parameters of frequency of communication, and quantity and quality of the information shared. The aim of this instrument is to determine the value of technical and social interaction in the flow of the collaboration, and the impact of the interaction in the development of the collaboration and in the solution of the design task. It is expected that this instrument provides also information regarding the perception and significance of this practice in different regions around the world.

The next step for this work is to collect data from students participating in this type of multinational collaborative projects. This process already started during the Fall 2013 and the first data collection was finalized at the end of January 2014 due to the class schedule for participants from Ecuador and Chile. The data collected will be analyzed to get an insight of the experience to determine if the desired objectives of this practice are being reached, and to make the necessary adjustments to identify the best tools for communication and best practices to improve the interaction and the design process during multinational collaborative projects. The validity and reliability of the survey will be also determined based on the data received and future assessment cycles. Results for the first assessment will be presented in another publication.

References

1. Shachaf, P. (2008). Cultural diversity and information and communication technology impacts on global virtual teams: an exploratory study. *Information and Management, Vol. 45, Iss. 2*, 131 - 142.

2. Davidow, W. H., & Malone, M. S. (1992). *The virtual corporation: Structuring and revitalizing the corporation for the 21st century* (Vol. 1st edition): HarperCollinsPublishers (New York).
3. Kotlarsky, J., & Oshri, I. (2005). Social ties, knowledge sharing and successful collaboration in globally distributed system development projects. *European Journal of Information Systems*, 37-48.
4. Carmel, E. (1999). *Global Software Teams: Collaborating across borders and time zones*: Prentice Hall.
5. Maury, H., Pinzón, R., & Esparragoza, I. (2008). International Collaborative Learning experience through global engineering design projects: A case study. . *Cooperative Design, Visualization and Engineering, 5220*, 212-215.
6. Duque, J., Esparragoza, I., Rodríguez, C., Banks, J. P., & López, J. M. (2010). *Assessing collaborative Global Design Projects among Engineering Students from US and Latin America.* Paper presented at the 8th LACCEI Latin American and Caribbean Conference for Engineering and Tecnhnology (LACCEI 2010): Innovation and Development for the Americas, Arequipa, Perú.
7. Papanikolaou, K., & Boubouka, M. (2010). Promoting collaboration in a Project-Based E-Leaning Context *JRTE, 43*, 135-155.
8. Helle, L., Tynjala, P., & Olkinuora, E. (2006). Project-based Learning in post-secondary education: Theory, Practice and ruber sling shots. *Higher Education, 51*, 287-314.
9. Barron, B. J., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., et al. (1998). Doing with understanding: Lessons from research on problem-and project-based learning. *Journal of the Learning Sciences, 7*(3-4), 271-311.
10. Jonassen, D. H. (1999). Designing constructivist learning environments. In C. M. Reigeluth (Ed.), *Instructional design theories and models: A new paradigm of instructional theory* (Vol. 2, pp. 215-239). Mahwah, NJ, London: Lawrence Erlbaum and Associates.
11. Land, S. M., & Zembal-Saul, C. (2003). Scaffolding reflection and articulation of scientific explanations in a data-rich, project-based learning environment: An investigation of progress portfolio. *Educational Technology Research and Development, 51*(4), 65-84.
12. Hannafin, M. J., & Land, S. M. (1997). The foundations and assumptions of technology-enhanced student centered learning environments. *Instructional science, 25*(3), 167-202.
13. McLoughlin, C., & Hollingworth, R. (2001). *The weakest link: Is web-based learning capable of supporting problem-solving and metacognition.* Paper presented at the 18th Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education.
14. Schank, R. C., & Cleave, J. B. (1995). Natural learning, natural teaching: Changing human memory *The mind the brain, and complex, adaptive systems* (pp. 175-202): Addison-Wesley publishing co.
15. O'Donnell, A. M., & King, A. E. (1999). *Cognitive perspectives on peer learning*: Lawrence Erlbaum Associates Publishers.
16. Teasley, S. D. (1997). Talking about reasoning: How important is the peer in peer collaboration? *Nato ASI Series F Computer and Systems Sciences, 160*, 361-384.
17. Teasley, S. D. (1999). The role of talk in children's peer collaboration. *Developmental Psychology, 31*, 207-220.
18. O'Donnell, A. M., & O'Kelly, J. (1994). Learning from peers: Beyond the rhetoric of positive results. *Educational Psychology Review, 6*(4), 321-349.
19. Dillenbourg, P., Baker, M., Blaye, A., & O'Malley, C. (1996). The evolution of research on collaborative learning. In E. Spada & P. Reiman (Eds.), *Learning in humans and machine: Towards an interdisciplinary learning science* (pp. 189-211). Oxford: Elsevier.
20. Esparragoza, I., Betancur, J. A., & Rodríguez, C. (2012). Designing for the Environment: an Undergraduate Case Study Supported by Global Collaborative Design. *International Journal of Education and Information Technologies, 6*(1), 25-32.
21. Davenport, S., Davies, J., & Grimes, C. (1999). Collaborative research programmes: building trust from differences. *Technovation, 19*, 31-40.
22. Jenkinson, L. R., Page, G. J., & Marchman, J. F. (2000). A model for international teaming in aircraft design education. *Aircraft Design, 3*(4), 239-247.
23. Potter, R. E., & Balthazard, P. A. (2002). Virtual team interaction styles: assessment and effects. *International Journal of Human-Computer Studies, 56*(4), 423-443.
24. Barron, B. J. (2003). When smart groups fail. *The Journal of the Learning Sciences, 12*(3), 307-359.