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Virtual Teams in Engineering – Global Practices

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1. Introduction

Competency Based Education (CBE), which focus on flexibility, mastery of abilities and the role of the professor as a coach, is fast expanding worldwide. This is the result of an approach that responds to current global needs. Universities are aware of the changes and challenges ahead, and are committed to developing "global citizens" [1]. One dimension they are working on, is the internationalization of their students.

The promotion of scientific and technological careers is on the agenda of international agencies and countries. It is expected that the demand of Science, Technology, Engineering and Mathematics *(STEM)* professionals will increase rapidly in the next 10 years. Also, the competencies they must have are going to change [2].

Labor market will have important changes. Collaboration between organizations to develop innovations will increase. Also, working activities will be interconnected and labor environment will be multicultural [3]. Under this context, future engineers will need to have knowledge on global technical requirements and standards; but, also to be productive working with partners who have different backgrounds and cultures [4]. In this sense, one of the abilities students must possess is collaborate with persons located in different geographical places, which is one of the main characteristics of working in *Virtual Teams* [5].

This paper explores *Virtual Team*s in the engineering field. A literature review was performed with the aim of present an overview on the topic, as well as state of the art regarding collaboration tools and the *Virtual Team* general practices of organizations promoting the development of related competencies. This paper is a source of valuable knowledge and bibliographical references regarding an issue of international interest, which is working in a more sustainable and innovative way. The outline of this paper is as follows: Section 2 presents a general outlook of *Virtual Teams*. In Section 3, collaboration tools are analyzed. Section 4 describes 8 case studies of organizations devoting efforts in promoting the development of *Virtual Team* competencies. Section 5 presents the *Virtual Teams* general practices of the aforementioned initiatives. The paper ends with conclusions in Section 6.

2. *Virtual Teams* overview

Teamwork has been essential for teaching students; it is appealing and stimulates the development of professional abilities. With the advancement of technology and globalization, the use of *Virtual Teams* is growing, leading to important changes and innovations in education.

Virtual Teams are "groups whose participants use information technology in functioning throughout locational, sequential, and interpersonal restrictions to undertake a codependent assignment" [6]. The use of Information and Communication Technologies (ICTs) for collaboration is mandatory in *Virtual Teams*. Developed projects are short-term, with a focus in innovation. Groups are small, with members located in different places. In this regard, *Virtual Team* members require certain competencies including: intercultural sensitivity, digital competency and managing complexity and uncertainty. All of them can be acquired with proper training, being universities a suitable place to promote its acquisition [7].

In research and development projects, such as the ones performed in engineering, two types of teams are used: Traditional and *Virtual Teams* [8]. Each of them has its own features, Table 1 [9–12].

Table 1. Traditional and *Virtual Teams* main features

Features	Traditional Teams	Virtual Teams
Main Characteristic	Individuals working in physical proximity	Individuals are physically separated
Communication	Members communicate face to face	Members are fully dependent on ICTs to communicate
Tasks performance	Members usually coordinate tasks together	Tasks are structured, with little space for coordination
Type of interaction	Members have social and informal interactions inside work	Members focus on work objectives and have little space for socializing
Innovation	Innovation takes place inside the organization and in working hours	Disruptive innovations can be generated. Individuals have more freedom
Leadership style	Leaders have more control on the activities and can track them daily	Leaders delegate more and assume the role of a coach
Main advantages	- Decision making can be done faster - Face to face interactions benefits the development of trust - Participants have similar cultures and backgrounds, decreasing conflicts	- Detects global changes faster and responds on time to demands -Time/money savings are possible -Collaboration projects are more productive
Main disadvantage	- Members have limited interaction with people outside the organization - The access to experts in a given field can be expensive or difficult	- An effective technological infrastructure is still expensive - Development of trust among team members is challenging

Virtual and Traditional teams do not replace each other. Their use depend on the type of project performed and the circumstances around it. *Virtual Teams* could be considered an extension of traditional teams [13]. In engineering education, researchers indicate that there are no significant differences between the performance of students working in face to face or *Virtual Teams* [14].

Some studies of *Virtual Teams* have focused on its environmental advantages [15], others in aspects of the individual [16]. This research presents the state of the art of practical knowledge for *Virtual Teams* to function. Useful tools and general practices of organizations promoting virtual work are analyzed.

3. *Virtual Teams* collaboration tools

Effective remote working and communication are the key aspects for a correct operation of *Virtual Teams*. Even though, until now, technological communication tools have proven to be unsuccessful in mimicking physical proximity [10], e-mails, chats, discussion forums and videoconferences [17] are among the effective tools used to organize *Virtual Team* tasks. Virtual reality also offers great advantages in distance work. It is expected that the advancements in this type of technology will have a major impact in engineering education [4]. Some of the collaboration tools used to assist *Virtual Team* working mechanisms are described and analyzed in Table 2 [18–21].

4. *Virtual Teams* education partnerships between universities/industries.

4.1 Partners for the Advancement of Collaborative Engineering Education (*PACE*) [7]. The *PACE* program was founded in 1999 by *UGS* (Siemens), *EDS* (Hewlett Packard), Sun Microsystems (Oracle) and General Motors. Today, it is a global educational consortium comprising 65 institutions from 12 countries. Its objective is to train future designers and engineers in a global collaboration context. A *PACE* project was developed in 2014 by a partnership between *Tecnológico de Monterrey* (México), *Virginia Tech* (USA), *Technical University Darmstadt* (Germany) and *Shanghai Jiao Tong University* (China). They developed a fully electrical vehicle concept in *Virtual Teams*. Technological tools were used including Facebook and Google Drive. It was determined that social networks improve communication and empathy among team members.

Table 2. Collaboration tools in *Virtual Teams*

Tool	Description	Use in Virtual Projects
Open Wonderland	Software for creating collaborative 3D virtual worlds. People can talk, share documents and interact almost in a real environment.	140 students of an introductory course were organized in groups to perform a *Virtual Team* project. It was determined that open spaces created in Open Wonderland increased team creativity [20].
IBM Sametime	Software that allow team communication and collaboration, both person to person or as a group. Screen sharing and multi audio calls are some of its features.	81 graduate students from a US university and an Indian school participated in a *Virtual Team* experiment using IBM Sametime. The voting and ranking tools of the software significantly reduced conflicts among team members [22].
GoToMeeting	Software that allow to collaborate in real time through online conferencing. Participants can schedule and record meetings, share screens, among others.	89 students of a southeastern university participated in a study aim at determining the influence of the media in *Virtual Teams*. GoToMeeting was considered a rich media, used for organizing tasks high in uncertainty and high in equivocality [23].
Facebook, Google+ and MySpace	This are used to make project discussions by creating sites/pages in which members can interact and, at the same time, socialize.	An organization of 122 scientists uses Facebook to discuss and promote virtual collaboration. This social media is not useful to collaborate directly, but facilitates the creation of trust [24].
Google Drive	Its main advantage is that users can work at the same time in one document and create them in site. It can make a *Virtual Team* more productive.	At a Sultan Qaboos University (Omán) course, students used Google Drive to collaborate in *Virtual Teams*. This tool facilitated collaboration as students could work at the same time, without sharing different versions of the document [25].
Skype	Offers individual or group communication which can take place through written chat, video or only voice. Users can share presentations and view documents with the screen sharing option.	A study with postgraduate students of an online course determined that Skype was the most effective and flexible communication tool for working virtually. The use of video enables to assess the body language, which improves communication success [26].

4.2 *HP* Catalyst Initiative [27,28]. *HP* Catalyst is a network of global educators, *NGOs* and policy makers who develop projects to improve *STEM* education. Under this initiative, students from *Coventry University* (UK) and *Ryerson University* (Canada) designed a building in *Virtual Teams*. The former assumed the role of civil engineers, while the latter acquired the role of architects. Tools such as Skype and Dropbox were used. It was determined that the virtual activity did not have an impact on students' performance. Participants were satisfied and stated that this experience will bring to them great employability opportunities.

4.3 Collaboration between *Virginia Tech* (USA) and *University of Southern California* (USA) [29]. These universities co-designed a Construction Engineering and Management (*CEM*) course for undergraduate and graduate students. The aim was to train them in real world construction projects, working in *Virtual Teams*. In the first course, students developed a Building Information Modeling (*BIM*) with the support of professors and industry mentors. Various tools were used including Doodle and Skype. Participants argued that *Virtual Teams* works best when there are no leaders. However, few natural leaders emerged during the project. Students were unsatisfied about virtual collaboration effectiveness to achieve the project goals. It was determined that *Virtual Teams* are not effective when the goal is to promote technical support.

4.4 The Global Studio Project [30], is the result of the changes in manufacturing, characterized by virtual partnership and design processes apart from production. A project was performed by students of *Loughborough University* (UK) and *British Telecom* (*BT*) (UK). All teams had to design and prototype technological solutions. The proposals included a smart wiring for houses. Expert of *BT* supervised each team through virtual meetings. Phone calls and Skype were the most used tools for communication. Participants were satisfied with the results; they learned how to incorporate the knowledge of different persons to achieve a common goal.

4.5 *DNV GL* Software Project [8]. *DNV GL* is an international software provider. In 2014, the firm organized a *Virtual Team* project between employees from Norway and Poland. The objective was to develop a web-based product. The Norwegians developed the core application and the Polish, the mobile version and plugins. Besides virtual communication, physical meetings were organized. It was determined that successful *Virtual Teams* are developed gradually and, most important, that each person must have team knowledge, i.e. understand the tasks, technical and personal characteristics of each member and the goals of the project, which gives certain autonomy.

4.6 Team-based European Automotive Manufacture (*TEAM*) project [31]. Engineers from 4 countries collaborated in this initiative. They used technology tools to make concurrent engineering automotive projects, such as designing steering components for a new vehicle program. Organizations involved included, among others, *Rover Group*, *University of Trento* and *Siemens AG*. The main goal was to enhance collaboration between car manufacturers and suppliers to reduce costs, time to market and enhance quality. The participants used the *TEAM* Demonstrator software to collaborate. It was determined that, in the automotive industry, the use of *Virtual Teams* with efficient communication tools could offer time savings from 10% to 50%.

4.7 Multinational Design Project [32]. This initiative was developed between students from universities in Chile, Colombia, Ecuador, Honduras, Italy and USA. The objective was that participants experienced working in *Virtual Teams*. They designed a machine to process and

pack fruit. An online meeting room was available; however, students also used tools such as Facebook and Google Docs/Drive. Half of the participants indicated that contribution to the project was equally among teams. The 77% of students indicated that there was a good disposition for working on time and actively. The 65% students argued that personal interaction was important to build trust.

4.8 The European Global Product Realization (*E-GPR*) project [13]. This initiative is developed between the *Swiss Federal Institute of Technology of Lausanne* (Switzerland), the *Technical University of Delft* (Netherlands), the *University of Ljubljana* (Slovenia) and an industrial partner. The goal was to teach students how to work in *Virtual Teams*. In 2003, participants developed a personal protective system for the welding industry. They were guided by the industrial partner and instructors from each university serve as mediators. The main communication tool was NetMeeting. It was determined that the *E-GPR* project is an efficient activity to teach students how to develop engineering designs collaboratively. The different backgrounds and culture of participants contribute developing innovative solutions.

5. *Virtual Teams* global general practices

The partnerships presented in Section 4 were analyzed based on five criteria related to *Virtual Teams* topic, Table 3. From its analysis, general global practices were detected, which are presented below.

The general practices that the organizations analyzed perform to train individuals to work in *Virtual Teams* were determined from Table 3 and are presented in Figure 1. Six categories were built based on the main *Virtual Teams* characteristics identified in the literature. The types of projects performed had a strong orientation toward the design and development of products in diverse fields: automotive, construction, technological, among others. The number of *Virtual Team* members varied. Groups were relatively small, with a maximum of 12 persons per team. Background category refers to the personal and professional characteristics of participants. Different majors, study levels and nationalities were combined. It was determined that diversity is a key aspect in *Virtual Teams*. Competencies developed in participants during the execution of the projects were also identified. The most mentioned included among others: communication, networking, digital competency and trust. As participants were located in different geographical areas, several technological collaboration tools were required. A mix of this tools was essential for facilitating communication and execution of tasks. Communication was more often done through email and Skype. Google Docs/Drive and Dropbox were effective to share documents and work simultaneously. This avoided handling different manuscript versions. Facebook was an excellent tool for developing informal ties and improve communication. Also phone calls were used for coordinating tasks directly. Students learning was assessed through individual and peer evaluations, written reports, oral presentations, projects and surveys. As different cultures were combined, a common language was necessary (e.g. English). All initiatives main goal was to train participants to face the challenges pose by the current global labor environment.

Table 3. *Virtual Team* characteristics of partnerships

Initia-tive	General characteristics	Type of project performed	Technology used	Developed competencies	Assessment method*
4.1	8 global teams were conformed. Each one had around 50 undergraduate and graduate students distributed in subgroups (4-5 members)	Design and development of an electrical vehicle	Teamcenter, Skype, Tandberg, WhatsApp, Facebook, WebEx, Google Drive and email	Networking, digital competency, communication, cultural awareness	Evaluation of reports and oral presentations
4.2	Groups of 8 undergraduate students were integrated. Students from different backgrounds participated	Design of a building	HP Virtual Room, Skype, Dropbox and email	Intercultural awareness, multicultural communication, management skills, trust, planning	Individual and peer assessment
4.3	11 students were from VTech and 12 from USC. Four multidisciplinary *Virtual Teams* were built with 6 or 5 members each. Undergraduate and graduate students took the course	BIM project	Synchro, Microsoft Project, Primavera, Digital Project, Doodle, e-mail, Google Chat/Docs, Skype, TokBox, Yugma, GoToMeeting and telephone	Digital competency, resource and time management, networking, leadership, trust, self-learning	Peer assessment, evaluation of reports and oral presentations
4.4	3 teams of 7 members each were built. Participants were master's level students	Designing and prototyping technological house solutions	Phone, Skype, web blog and email	Communicating, supporting, leading, proactivity, analyzing	Oral presentations and evaluation of reports
4.5	12 Norwegians comprised one team and 10 Polish the other. They were software developers and testers	Development of a web-based software product	Discussion forums, video conferences, Slack collaboration tool	Communicating, networking, autonomy, responsibility, continuous learning	Students were not involved in this project
4.6	40 engineers collaborated in 10 project teams. Four countries were involved	Concurrent engineering projects in the automotive industry	*TEAM* Demonstrator which includes tools as multimedia conferencing	Digital competence, planning and organizing, communication, efficiency and effectiveness	Students were not involved in this project
4.7	100 students from 6 countries participated. Local teams (subgroups) of at least 3 members and clusters of at least 4 subgroups were organized	Design of an industrial machine	Online meeting room, audio-video conference, Google docs/drive, e-mail, Dropbox and Facebook	Digital competence, effective communication, teamwork, auto-motivation	Student's survey
4.8	Teams of 3 students were organized. Master of science students of different backgrounds participated	Engineering product development	Video-conferencing, NetMeeting, AOL messenger, Yahoo-chat, E-mail, blackboard	Planning, organization, networking, trust, responsibility	Project based

*As there are projects in which students were not involved, a proper comparison of the students' assessment methods of all initiatives is difficult. However, this information is available from 6 out of 8 projects analyzed and hence is presented in the corresponding column.

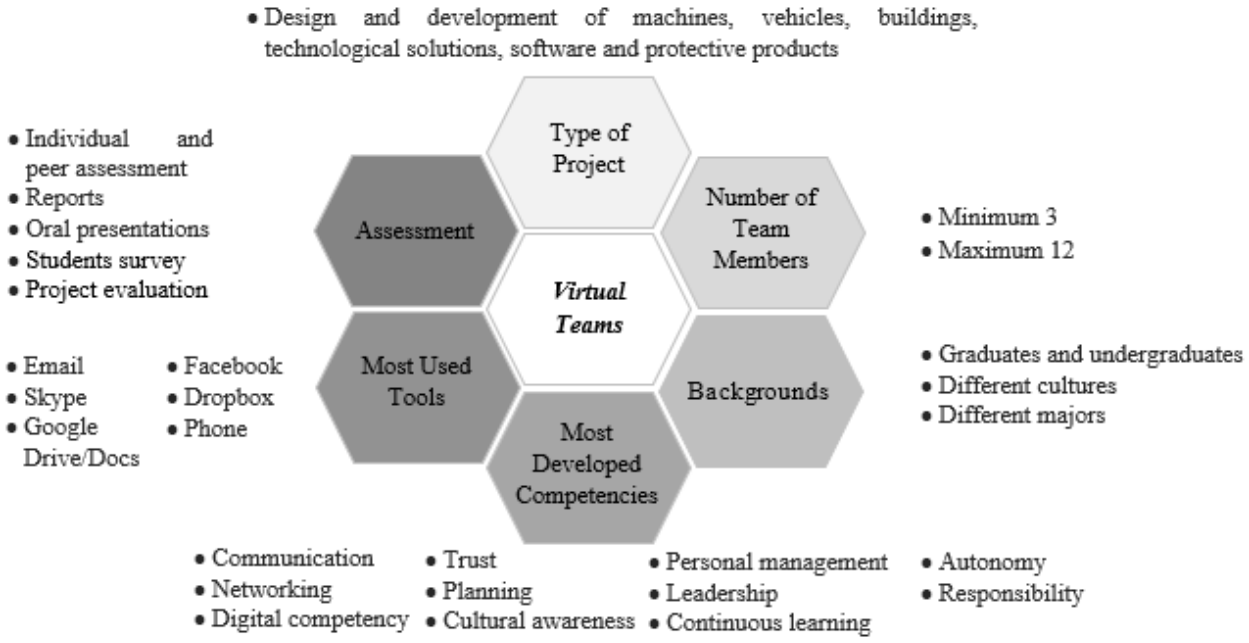

Figure 1. Organizations' general practices

6. Conclusions

Virtual Teams main characteristic is the location of members in different geographical areas. Therefore, it is mandatory that individuals involved in a virtual project use a mix of technology tools to work effectively. The different knowledge, backgrounds, cultures and experiences of *Virtual Team* members foster disruptive innovations. This is especially useful in projects involving research and development activities. Besides above advantage, individuals facing virtual work develop useful competencies for performing effectively in a competitive labor environment. These include networking and digital competency. Communication problems were identified during the execution of some projects researched. This is mainly the result of the cultural and language differences. It was stated that working in *Virtual Teams* is kind of difficult, mainly to achieve the project goals. Interesting results were detected in this research. First, social networks can improve communication as they foster informal relationships. Second, an effective *Virtual Team* is built gradually; time is needed to determine what works best for the team. Also, regular in person interactions are required to develop trust among team members. Third, *Virtual Team* learning experiences does not necessary improve individuals' performance. Finally, *Virtual Teams* are not useful when the aim is to promote technical support among team members.

References

1. Hasler BS. Intercultural Collaborative Learning in Virtual Worlds. *Cutting-Edge Technol High Educ*. 2011;4:265-304.
2. Telefonica Foundation. *Educational Top 100 Innovations*. https://en.fundaciontelefonica.com/education/.
3. Hernández M, Morales R. Current Trends in Competency Based Education. *World J Eng Technol*. 2016;04:193-199.
4. Shuman L, Besterfield M, McGourty J. The ABET " Professional Skills " – Can They Be Taught ? Can They Be Assessed ? *J Eng Educ*. 2005;94(1):41-55.

5. Li X. Work in Progress - Students and Engineers Collaborating in Global Virtual Context. In: *IEEE Int Professional Comm Conf.* ; 2014.
6. Gonzalez M, Velez A, Cathro V, Caprar D, Taras V. Virtual Teams and International Business Teaching and Learning: the Case of the Global Enterprise Experience (GEE). *J Teach Int Bus*. 2014;25(3):200-213.
7. Orta P, Urbina P, Ahuett H, Hernández M, Morales R. Social Collaboration Software for Virtual Teams - Case Studies. *Int J Interact Des Manuf*. 2017:1-10.
8. Moe NB, Faegri TE, Cruzes DS, Faugstad JE. Enabling Knowledge Sharing in Agile Virtual Teams. *2016 IEEE 11th Int Conf Glob Softw Eng*. 2016:29-33.
9. Ebrahim N, Ahmed S, Taha Z. Virtual Teams: a Literature Review. *Aust J Basic Appl Sci*. 2009;3(3):2653.
10. Hinds P, Kiesler S. *Distributed Work*. 1st ed. Cambridge: MIT press; 2002.
11. Hunsaker P, Hunsaker J. Virtual Teams: a Leader's Guide. *Team Perform Manag An Int J*. 2008;14(1/2):86.
12. Management Study Guide. Virtual Team - Origin, Definition and its Scope. http://www.managementstudyguide.com/virtual-team.htm. Oct 7, 2016.
13. Bufardi A, Xirouchakis P, Duhovnik J, Horvath I. Collaborative Design Aspects in the European Global Product Realization Project. *Int J Eng Educ*. 2005;21(5):950-963.
14. Whitman L, Malzahn D, Chaparro B, Russell M, Langrall R, Mohler B. A Comparison of Group Processes , Performance , and Satisfaction in Face-to-Face Versus Computer-Mediated Engineering Student Design Teams. *J Eng Educ*. 2005;94(3):327-337.
15. Olaisen J, Revang O. Working Smarter and Greener: Collaborative Knowledge Sharing in Virtual Global Project Teams. *Int J Inf Manage*. 2017;37(1):1441-1448.
16. Connelly C, Turel O. Effects of Team Emotional Authenticity on Virtual Team Performance. *Front Psychol Front Psychol*. 2016;7(7):1-13.
17. Gheni A, Jabar M, Jusoh Y, Ali N, Abdullah R. Factors for Communication Technologies Selection Within Virtual Software Teams. In: *2015 9th Malaysian Software Eng Conf.* ; 2016:76.
18. Barczyk CC, Duncan DG. Social Networking Media: An Approach for the Teaching of International Business. *J Teach Int Bus*. 2012;23(2):98-122.
19. Chilton M. Technology in the Classroom: Using Video Links to Enable Long Distance Experiential Learning. *J Inf Syst Educ*. 2012;23(1):51-62.
20. Minas RK, Dennis AR, Massey AP. Opening the Mind: Designing 3D Virtual Environments to Enhance Team Creativity. In: *Proc Annual Hawaii Int Conf on System Sciences*. Vol March. ; 2016:247-256.
21. Schroeder K, Hammer S, Maylath B. Synchronous and Asynchronous Online International Collaboration. The Trans-Atlantic & Pacific Project. *Int Prof Commun J*. 2015;3(1):153-177.
22. Paul S, Ray S. Cultural Diversity , Group Interaction , Communication Convergence , and Intra-group Conflict in Global Virtual Teams. In: *46th Hawaii Int Conf on System Sciences*. ; 2013.
23. Bryant S, Albring S, Murthy U. The Effects of Reward Structure , Media Richness and Gender on Virtual Teams. *Int J Account Inf Syst*. 2009;10(4):190-213.
24. Murthy D, Lewis J. Social Media, Collaboration, and Scientific Organizations. *Am Behav Sci*. 2015;59(591):149-171.
25. Sadik A. Students' Acceptance of File Sharing Systems as a Tool for Sharing Course Materials: The Case of Google Drive. *Educ Inf Technol*. 2016.
26. Ladyshewsky R, Pettapiece R. Exploring Adult Learners Usage of Information Communication Technology during a Virtual Peer Coaching Experience. *Online Learn J*. 2014;19(2):1-15.
27. Johnson, L., Adams S., Estrada, V. RK. *HP Catalyst Case Studies in Innovation*. Austin, Texas; 2012.
28. Kärkkäinen K, Vincent-Lancrin S. *Sparking Innovation In Stem Education With Technology And Collaboration: A Case Study Of The HP Catalyst Initiative*.; 2013.
29. Becerik-Gerber B, Ku K, Jazizadeh F. BIM-Enabled Virtual and Collaborative Construction Engineering and Management. *J Prof Issues Eng Educ Pract*. 2012;138(3):234-245.
30. Global Studio. Welcome To The Global Studio! http://theglobalstudio.eu/. Nov 4, 2016.
31. Liang AZ, Jin YH. Transactive Memory Systems in Multi-Teams Cooperation. *Proc - 3rd Int Conf Inf Manag Innov Manag Ind Eng ICIII 2010*. 2010;4:3-7.
32. Esparragoza IE, Farak SL, Ocampo JR, et al. Assessment of Students' Interactions in Multinational Collaborative Design Projects. *Int J Eng Educ*. 2015;31(5):1255-1269.