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Virtual Engineering Design Teams

Abstract

Globalization has moved to the forefront in industry today; more and more companies have to face a global work environment. As a result, global teams with members scattered across the globe have progressively emerged. At the same time, a revolution, coined as the "v-revolution," is slowly creeping into business proceedings. The v-revolution describes the emerging growth in the use of virtual worlds. Virtual worlds, such as Second Life®, are gradually evolving as common business practices. Some companies, such as IBM, currently use the medium to conduct meetings and others, such as Nissan, are using its 3D design capabilities to build prototypes. These two emerging tendencies are being integrated to create what is known as the virtual engineering design team. These are global teams consisting of several engineers geographically distant, aiming at a common design.

In light of these progressive changes in industry, notable in engineering as well, it becomes apparent that a new generation of engineers will be needed; a generation of virtually apt engineers. This paper will present a thorough literature review of the characteristics and specifics of such teams; particularly it will look at the problems and advantages portrayed in the available literature. As a result of our findings, improvements, adaptations, and possible new directions in the education of the future engineers will be suggested.

Introduction

Virtual engineering teams may become dominant in a future where globalization and competitiveness will require faster and more international team settings. As the environment requires more cost containment, organizations are transforming into virtual organizations. Even engineering organizations are following the trend and developing virtual engineering design teams, also known as e-engineering teams, which have the capability to have a distant panel of experts who not only improve the design process, but also deliver a more cost competitive product. Virtual teams are also able to provide flexibility in product design which has become more and more crucial to companies as they seek to meet the needs of their widespread and diverse markets Furthermore, even if business itself does not push the transition into virtuality, this will be brought forward by the upcoming workforce. In fact, virtuality already is the common practice of the uprising workforce. This uprising workforce which is none other than the Y generation is mainly characterized by its technology affinity, with their use of social networks, instant messaging, blogging, virtual worlds immersion etc. In fact, as the Y generation, also known as the "digital natives," is progressively entering the workforce; the "virtual world" will progress into reality as well.

As we advance further into the digital age, virtual engineering teams may become the norm for engineering teams; a key imperative for modern business proceedings. As a result, more research as to be undertaken in order to understand the dynamics of these teams along with the other key characteristics.

The aim of this paper is to present a thorough literature review of the research that has been done in this area. Specifically we will look at the drivers of global design teams, the effectiveness and challenges of global design teams, including communication, technology, and geographical, social and cultural complexities. The result of this study will enable educators to assess the changes and directions needed in engineering education in order to provide industry with the type of engineers needed for the future.

Virtual teams

Since the emergence of the concept of "virtual team", there have been many definitions for the concept. However, as the concept becomes more and more widespread, researchers and practitioners tend to converge to the following definition: "a virtual team is a group of geographically and organizationally dispersed workers brought together across time and space through information and communication technologies to accomplish an organizational task. A virtual team is a collection of individuals who think, feel, and act as an interdependent unit and who are recognized by others to constitute a virtual team" [1]. With the concept of virtuality, the notion of "working together apart" [2] very well captures the essence of what the virtual world presents to organizations. In fact, people no longer have to be confined in the same continent, let alone building or room, in order to work on a project. The new face of organizations is that of a much decentralized group, with diverse sub-groups dispersed all over the four corners of the world. Virtual teams and networked organizations are the latest stage in the evolution of organization [3].

Virtual teams are a type of small group. They differ from other small groups in forms of communication, number of relationships, and in the ability to create in a global context. The technology is here today that allows people to work together at a distance just as though they were next door to one another in an office setting. [3]

In terms of engineering, global virtual engineering teams are defined as the collaboration of several people, geographically scattered around, working towards a common goal to design a product or process. This is an adaptation of the definition of virtual team to engineering team. Dryer et al. coined this concept as "e-engineering", which they further define as "distributed collaboration in cyberspace using leading edge technologies enabling physically-dispersed, diverse teams to create integrated, innovative and competitive products, systems, and services" [4].

The literature on the subject of virtual teams abounds with examples of virtual teams that have had enormous success. One is the example of Valent Software characterized as "the emblem of the twenty-first-century" by Lipnak and Stamps [5]. The company's 10 employees never really co-located, yet within three years they turned a $700,000 investment into a $45 million sale to a major web portal. They provided Lycos Clubs, a community-building facility critical to the success of the Lycos search engine [5].

The spread of virtual teams is attributed to many factors. Two leading factors include advances in technology and globalization. Technology advances have allowed for faster and more effective communication. Globalization has prompted companies to be

geographically scattered in order to not only adapt to the changes but also as a basic survival necessity due to stiffer competition.

Needs or circumstances that make virtual design teams necessary

Globalization has affected every aspect of business and industries. Engineering design has not escaped this globalization trend. As a result, more and more engineering virtual teams have spawned. This trend has several roots; in fact aside from globalization, the increase in global competition and the advances in technology have also been drivers in the burgeoning of virtual engineering teams.

With the growth of multinational corporations, competition in the world marketplace is relentless. This competition is amplified by the current worldwide economic downturn. Those who can get the highest quality, price-competitive product to market in the least time are going to be winners. To respond to this challenge by merely cutting prices and work forces to maintain profit has been proven to be a misguided strategy; rather, the success results from understanding customer needs, developing a product to meet those needs, bringing that product to market quickly and at a fair value [6].

The current approach is more towards virtual teams that collaborate across geographical, temporal, cultural and organizational boundaries to achieve global maxima in design. Design teams, therefore, increasingly need to make extraordinary efforts to establish and maintain a sense of communication, co-location, coordination and collaboration. Software tools and hardware solutions that support such distributed design teams have thus become a necessity rather than a fad [7].

In 2000, Dryer et al. reported that the National Research Council (NRC) Committee on Advanced Engineering Environments expected significant changes in engineering product design, project processes, collaboration support and education in training within the upcoming seven years (NCR, 2000 as reported by Dryer et al., 2003) [4]. These changes were the apparition of more and more global engineering design teams.

In their paper, Bushari et al. provide the statistics of companies outsourcing their engineering designs; these statistics were collected by the Aberdeen group. The report, which dated from 2005, provided the following numbers:

- 59% of companies with global design strategies in place
- 44% currently pursuing global design networks
- 28% currently outsourcing some design or engineering [8].

This reported growth trend of engineering design outsourcing was projected to grow in the coming years. More specifically, a 59% increase in the outsourced design to offshore companies was predicted, along with an increase in design outsourced to company-owned offshore design centers of 58% [8].

Competition has surely driven the rise of virtual teams. Nowadays, having a competitive product requires not only marketing but also a reduction in the cycle time and costs of

products. Many engineering and manufacturing firms realize that it is critical to have a presence (facilities, people) around the world to be able to compete internationally. Along the same lines, many firms are establishing strategic international partners to face marketing challenges. The role of the "core" organization changes in this global environment needs to adjust to the increased roles and responsibilities of alliance partners [9]. The responsibilities of partners may include anything from engineering and manufacturing of products, to marketing, sales and service support. Deliverables, which such enterprises develop and produce, have more engineering complexity and integration requirements. Projects need to be completed under tighter budget constraints for enterprises to remain competitive.

Since the invention of the internet, we have entered the "digital age," also called the "internet age". The advance in technology is a sure driver for the progress of virtual teams. Since the creation of the internet, companies have searched ways to exploit the new tool. Distance-defying communication opens up vast new territory, unbounded by space or time, for virtual teaming. For the first time since before nomads moved into towns, work is diffusing rather than concentrating. Officially, we have moved from the industrial age to the information age [5]. As a result, face-to-face meetings have progressively been replaced by computer-aided interactions (communication). In fact, with the advance in technology, emails, video and phone conferencing have become increasingly in practice over the conventional face-to-face meetings; they have often appeared as the new norm.

Now a new wage of technology is sweeping into business; that is the development of virtual worlds. Virtual worlds have been rising in success just as the www revolution was in the late 1990's. One of the most prominent is Second Life®. Second Life® is 3-D virtual world that simulates an area about the size of Washington, D.C. [10]. Since its creation by Linden Lab in 2003, it has grown tremendously and as of April 2008 was inhabited by 13,448,143 residents from around the globe.

Second Life® is often described as a game, in the broad sense that its users participate because they enjoy it. Unlike World of Warcraft®, for example, there are no competitions or points to be won. It is intended, as its name indicates, to provide its participants with a "second life" in which they customize themselves [11]. In fact, much of the attention paid to Second Life® has been propelled by its embrace of open source software, which allows its users to design their own environments and virtual goods. Any virtual design good becomes the intellectual property of the designer and can, like a real good, have some value placed upon it.

Problems encountered

The problems encountered in virtual teams are common to all type of teams; whether they are engineering design teams, or marketing teams, or team of researchers. This section presents the problems related to virtual teams which are most persistent in the literature.

Due to their global composition, virtual teams generally encompass people diverse in their language, nationality and culture. Though it may be the case also in face-to-face teams, this is more exacerbated in the context of virtual teams. In fact, one consistently recurring theme present in the literature is the difficulties due to the cultural diversity in virtual teams. Research indicates that conflicts and other troubles occurring in virtual teams are often highlighted. It is important to note that there can be negative as well as positive aspects of diversity in virtual teams. The positive aspect coming from this diversity is the team's ability to generate multiple and different perspectives to a question. This, according to Jehn et al. [12], increases creativity, innovation and flexibility. On the other hand, cultural diversities may cause a decrease in team performance. Indeed, Kayworth and Leidner [13] argue that cultural differences are one salient source of difference that may have an important influence on how individuals perceive information, act on it, and relate to other individuals in a virtual team.

Staples and Zhao [14] attempted to determine the impact of cultural diversity in virtual teams and also in traditional face-to-face teams. The results from the study showed that the heterogeneous teams were less satisfied and cohesive and had more conflict than the homogeneous teams, although there were no statistical differences in team performance levels. However, an examination of only the heterogeneous teams found that the performance of the virtual heterogeneous teams was superior to that of the face-to-face heterogeneous teams [14]. These results show two things: first, virtual teams may be more effective than face-to-face teams; and second, for virtual teams to be even more effective, cultural diversities and conflicts have to be understood and overcome.

Trust is another issue that arises in the virtual team setting. Indeed, "trust is the glue of the global workspace and technology doesn't do much to create relationships" [15]. Trust is critical in virtual teams for reducing the high levels of uncertainty endemic to the global and technologically based environment [16].

In their research, Krebs and Bordia [17] studied the effect of dissimilarities (based on age, gender, country of birth and enrolled degree) on group trust. The results of the research are the following:

- In face-to-face groups, a negative relationship existed between age dissimilarity and trust, such that individuals who were more dissimilar in age to other group members reported lower levels of trust in group members.
- In virtual settings, it was found that individuals trusted each other regardless of the level of demographic dissimilarity.
- In face-to-face groups, no relationship was found between birthplace dissimilarity and trust, whereas in virtual groups a positive relationship was found between birthplace dissimilarity and trust.

This increase in trust in the virtual team is opposite to the results of similar studies found in the literature. Krebs and Bordia [17] explained this discrepancy by the fact that in the virtual groups, it was found that more than half of participants high in birthplace dissimilarity (above the median) were from collectivist cultures, such as China and the Philippines. In a work group situation, collectivists are more likely than individualists to

sacrifice personal interests for the attainment of group goals and are more likely to enjoy doing what the group expects of them. For example, collectivists tend to engage in more cooperative behavior than individualists in a diverse work team. Krebs and Bordia found that in an ethnically diverse work team, collectivists (Japanese) initiated less conflict and used less competitive tactics than did individualists (European-Americans). Thus, individuals high in birthplace dissimilarity may have perceived higher levels of trust based on their collectivist values of a more cooperative attitude toward group work. Further research, however, is required to clarify the findings [17].

Communication and information are often central components of distance work. Indeed, communication is the main vehicle for keeping a team together and moving forward [18]. Despite their physical separation from the office, workers are expected to remain connected to the organization. The most obvious manifestation of this connection is through communication. As a result, workers employ various means to communicate. The communication methods have been separated in two groups: synchronous and asynchronous. Synchronous communication methods are ones that allow for instantaneous, interactive, same-time conversations. The methods include face-to-face interactions, instant messaging, videoconferencing, conference calls, etc. Asynchronous methods, such as email and blogging, have a time delay from sender to receiver. The virtual worlds, such as Second Life®, offer both synchronous and asynchronous methods. They provide text messaging, IM (instant messaging) and live chats between users via avatars.

Many of these communication types rely heavily on telecommunication. Hence, another matter involves the potential technical issues, such as connection speed or system breakdowns that come with the use of technology. However, with the advances in technology, this will become less of an issue as compared to others.

Time zone differences, coupled with issues of communication, become a source of trouble in global virtual teams. As established earlier, virtual teams are often geographically scattered and often also separated in widely different time zones. For example, Central European Time is seven hours later than Central Standard Time (US), but seven hours earlier than in China. As a result, communication, asynchronous as well as synchronous, becomes difficult. In fact with time differences, team members often have to stay very late or arrive very early in order to meet other members in different time zones. Additionally, the different notions of time and urgency in different part of the worlds can prevent share appreciation of project deadlines, work pace or rhythm and importantly, performance measures where time is chargeable [19].

Advantages of sork in a virtual world

First and foremost, virtual worlds offer 3-D design of virtual objects which would facilitate the design, production and development of new products. With the residents free to design their own virtual environment and objects, teams would easily develop their products. Furthermore, these would be protected by the Intellectual Property (IP)

law in Second Life®, which basically says that the residents own the IP to anything that they build.

The application of virtual engineering design also facilitates an enriched communication between and among participants. It allows for efficient and fast knowledge transfer. Team members can interactively evaluate virtual prototypes of product designs and evaluate alternative scenarios. They will be able to make decisions quicker since all team members share the same information.

Furthermore, virtual worlds can provide an advantageous place to test a product. In fact, some architects are building designs that their clients' avatars can walk through to see if they like the idea. Starwood Hotels has built a loft hotel in Second Life® and invited people to "stay" in its rooms in an attempt to see if the design might work in the real world. Nissan has virtual showrooms where avatars can take a drive test and provide the company with their feedback.

The cost benefits of going virtual come in different forms. The cost of product development, design and production are reduced. Products can be developed with more interaction in less time and at a reduced cost [4].

Kisielnicki, in his study of the transformation of small and medium business into virtual organizations, noted that in the analysis of unit costs of production by manufacturing enterprises in the traditional organizations reaches an optimum point; i.e., after reaching a certain threshold, unit cost grows. In the virtual organizations, however, unit costs may permanently decrease as volume of production increases [20].

Another form of cost cutting comes from reduced travel. With the use of virtual team meetings, traveling can be drastically reduced, thus leading to a substantial cut in traveling costs. In fact, according to Lipnack and Stamps [5], Ernst & Young International's chief information officer, John Whyte, reduced travel by 35 to 40 percent with virtual teams.

More competitive design/leveraging expertise. One main characteristic of virtual teams is their ability to generate and share design ideas. The use of technology allows for sharing and easy modification of design drawings. Furthermore, the diverse composition of the team and the live connectivity with global experts allow for an enriched and leveraged expertise. This also enables the designed product to reach a wider global market since each expert knows how to meet the needs and expectations of their corresponding geographic market.

Summary of findings

The table below presents a summary of the literature reviewed. It categorizes articles in five different types as follows:

- Organization: corresponds to the studies which looked at the organizations of virtual teams, i.e. the components/structure of such teams, the hierarchy of the organization and other characteristics specific to such team.
- Design: these studies focuse on the engineering design/ product development process in virtual teams.
- Technology: in these studies, the focus was geared toward the analysis or development of the technology supporting virtual teams.
- Sociocultural studies mainly looked at the human interactions and the consequence brought forward through virtual teams and their diverse nature.
- Cost, looked at the cost associated with going virtual.

Table 1. Focus of research in virtual teams.

Author	Year	Title	Categories				
			Organization	Design	Technology	Sociocultural	Cost
Kim, Lyons,and Cunningham	2008	business models: evaluating service innovations in second life	✓	✓			
Lee-Kelley, and Sankey	2008	Global virtual teams for value creation and project success: A case study,	✓	✓	✓	✓	
Bushari et al.	2007	Managing Global Teams	✓	✓	✓	✓	
Edwards	2006	Another World			✓		
Staples and Zhao	2006	The effects of cultural diversity in virtual teams versus face-to-face teams," Group Decision and				✓	
Krebs and Bordia	2006	Virtual teams and group member dissimilarity, consequence for the development of trust				✓	
Kisielnicki	2005	Virtualization as a Process of Transformation for Small and Medium Enterprises (SMEs) in the	✓	✓			✓
Dryer, Jacobs and Swart	2003	The model for e-engineering team adaptation (MeTa): a project framework to improve			✓	✓	
Lipnak and Stamps	2000	Virtual Teams		✓	✓	✓	
Pena-Mora et al.	2000	Cairo: a concurrent engineering meeting environment for virtual design teams		✓	✓		
Kayworth and Leidner	2000	The Global Virtual Manager: A Prescription for	✓			✓	
Lipnak and Stamps	1999	Virtual Teams: The new way to work	✓		✓	✓	
Jehn et al.	1999	Why Differences Make a Difference: A Field Study of Diversity, Conflict, and Performance in	✓			✓	
Mills	1998	Collaborative engineering and the Internet		✓	✓		
Jarvenpaa, Knoll and Leidner	1998	Is anybody out there? Antecedents of trust in				✓	
Henry and Hartzler	1998	Tools for virtual teams		✓	✓		
Grenier and Metes	1995	21st century		✓	✓	✓	
Jin et al.	1995	The Virtual Design Team: Modeling organizational behavior in concurrent design	✓	✓	✓		
O'Hara-Devereaux and Johans	1994	Global work: Bridging distance, culture, and time		✓		✓	
Wang, Huang and Wang		Intelligent virtual team in collaborative design	✓	✓	✓		

From the study of this literature, the main findings were that:

- Virtual teams have been found to be efficient in increasing the productivity of an organization as compared to a traditional team. In fact in most of the studies, it was not found that there existed a significant difference between face-to-face traditional teams and virtual teams. However, in some instances, virtual teams appeared to be more effective when properly "managed".
- There are two facets to the diversity of virtual teams: on one hand it provides a wide range of expertise which generates greater innovation and competitive in the designed product. On the other hand however, the same diversity is the source of friction due to cultural lags and barriers. These socio-cultural issues, often coupled with communication problems, have been recurrent issues which have yet to be resolved since the uprising of virtual teams. This dynamic suggest that virtual teams demands a new type of management style and/or tools, which have yet to be found. It is therefore, an area for future research to study for virtual teams' efficient management styles.
- As far as the technology is involved with virtual teams, it has been found that much improvement occurred since the emergence of these teams. The impedance caused by technological failures have been for the most part resolved and are nearly inexistent.
- Last but not least, in general, virtual teams are characterized as a method of cost cutting, which often the main driver for the transition to virtual organizations.

Conclusion

Virtual design teams are slowly and surely becoming the new face of engineering design. With globalization, the economic downturn, and the resultant increasingly fierce competition, organizations have to improve their designs, streamline their processes, and trim their costs as much as possible. Virtual worlds can facilitate this and even enhance the marketing of products. As a result, more and more companies are adopting global virtual teams.

From the study of the available literature, virtual teams have presented both advantages and disadvantages.

The first and foremost advantage is the cost cutting; as seen in the literature, virtual teams are effective cost cutting tools. They also have the virtue of increasing productivity and innovation, as they allow for an instantaneous yet distant melting pot of experts. However, as much as the diversity of virtual teams is a great asset, it can also become a disadvantage. In fact, the literature indicates that with the spread of virtual teams across the globe comes a cultural diversity that tends to generate some gaps in behavior and understanding, as well as lack of trust among the team members. Thus to experience the full virtues of virtual engineering teams, their effective management must be achieved. This has yet to be achieved according to the results present in the literature. As such, the challenge now is not only to study these systems and find the most appropriate management techniques, but also to form the next generation of engineers who most

likely will be required to possess the skills to manage and/or evolve in these global virtual teams.

It becomes therefore the imperative for the core of engineering education to "manufacture" the next generation of engineers, who will be able to thrive in this developing engineering environment, that of global virtual engineering teams. Future research should therefore look at implementing virtual engineering design teams in new college students and study how to effectively implement and manage these types of teams in order to achieve greater success.

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