Toward Understanding Costs and Benefits of Virtual Teams in Virtual Worlds

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***Abstract*—Virtual teams offer the promise of accelerated product delivery at minimal cost. Coupled with virtual worlds, computer-generated space where users can network throughout the world, technical work may be done in ways and places not yet imagined. This paper explores the potential costs and benefits that arise from virtual teams and virtual worlds. From these, the beginnings of a systematic understanding of the tangible and intangible life cycle issues associated with virtual teams in virtual worlds will be proposed.**

***Index Terms*—engineering design, life cycle costing, virtual teams, virtual worlds.**

I. Introduction

The old paradigm of work is slowly fading away, if not already gone. The prevailing assumption that to work together, members of a team must collocate is rapidly being overturned. This shuffle, not to say paradigm shift, has been driven by the steady rise of virtual teams in the workplace. Advances in technology have indeed made many traditional teams obsolete in favor of virtual teams that defy the place, time, and any form of geographical boundaries. Virtual teams have become possible with the www revolution of the mid-1990's. However, it was not until the late 1990's that the gradual shift toward virtual teams began to take place. With the rise of the internet, companies quickly saw the benefits of the new technology, thus starting to explore its potential uses. This resulted in the steady move towards virtual teams using emails, chats, and later videoconferencing. As explained by Lipnack and Stamps [1], face–to-face interactions have always been the traditional way for human beings to socialize and interact. However, in this digital age, one no longer has to be in the same building, never mind same continent, to work together. People are organized around virtual teams that transcend distance, time zones and organizational boundaries [1, p. 4]. Already in 2000, some researchers and practitioners predicted that virtual teaming would become the norm, the survival skills in the 21st century; fast-forward to 2009 and, indeed, virtual teams have now become ubiquitous building blocks in organizations.

With the rise of the digital age and the subsequent rise of virtual teams, geographical boundaries and limited cooperation no longer exist. People in different buildings, different regions and different countries are teamed together through the communication highway; virtual teams have indeed become the building blocks of organizations. Just as people have evolved from tribes to networked organizational structures, virtual teams are evolving into another dimension, immersing themselves into 3D environments.

Virtual Reality will be, within the next decade the "must have" new technology for engineering, according to many companies. The research that was being done in renowned universities that delve into the research poised to be the next big technology, such as the University of Iowa (Virtual Reality Applications Center) and the University of Arkansas, was already hinting to the fact that virtual worlds would be the next must-have in engineering design. Though a decade has passed since these predictions were made, virtual reality has not achieved such a widespread use, at least not in the engineering and design industry. There are many reasons for this, including high costs, prematurity and limitations of the then-new technology. However, virtual reality use is once again gaining momentum and this time it appears not to be a fad but rather here to stay. In fact, many factors seem to point to an inevitable adoption of the technology. The technology has now matured much more and costs have plummeted, and most importantly, the digital era has given birth to a generation of avid technology users known as the "digital natives" to whom navigation in immersive worlds comes naturally.

In this paper we propose our research endeavors. First, we will review the literature about virtual teams; more specifically, the paper will focus on the factors of team effectiveness that previous work has found to be the fundamental factors contributing to team effectiveness. Next, we will look at virtual worlds; what they are, the opportunities they entail, and some of the research questions they have sparked. Last, we will formulate our research inquiry.

II. Review of Virtual Teams

Despite their predominance, virtual teams are still facing issues as far as achieving their optimum effectiveness. These problems are attributed to factors such as lack of trust, lack of effective communication, lack of coordination, difficulties due to cultural differences etc. The literature review by Cissé and Wyrick [2] highlighted some of the most recurring issues present in the literature about virtual teams. It was found that for a team to be effective, group members must have high trust, as trust is the glue for the team, and any relationship for

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that matter. In fact as Robert et al. [3] state, trust will not only encourage more information sharing among team members who communicate through digital networks but also ensure the use of that information. Thus, presence of trust helps counteract the detrimental effects of computer mediation on knowledge integration.

Knowledge integration, also commonly referred to as knowledge sharing, is also another core factor necessary for a well functioning team. Teams are formed with the underlying assumptions that team members each possess information and skills unique to them, though sometimes team members' skills overlap, it is most common that they are complementary. As such, knowledge sharing is capital to the proper and effective execution of a task, especially when a team is performing highly interdependent tasks. Some researchers often argue that knowledge is the most important capital an organization possesses; as Robert et al. [3] assert, the cumulative knowledge that a company is able to access from inside and outside the organization is often regarded as a sustainable resource for competitive advantage. In a study of Korean government workers, Kang et al. [4] found a high correlation between knowledge sharing and work performance; in fact, they implied that individual work performance may be dependent on the effective use of knowledge sharing. Through their study, it was also confirmed that mutual trust is a mediator between knowledge sharing and work performance. Additionally, knowledge sharing increases team efficiencies through the prevention of redundancy, as employees have acquired and shared their knowledge and information such that the same problems are not solved more than once.

Having a shared mental model is also deemed as a fundamental factor for team effectiveness. According to Mathieu et al. [5], mental models serve three crucial purposes: they help people to describe, explain, and predict events in their environment. Rouse and Morris [6] defined mental models as "mechanisms whereby humans generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states." A simpler explanation is given by Mathieu et al., "Mental models are organized knowledge structures that allow individuals to interact with their environment. Specifically, mental models allow people to predict and explain the behavior of the world around them, to recognize and remember relationships among components of the environment, and to contrast expectations for what is likely to occur next" [5].

Returning to the effect of shared mental models on teams, Robert et al. [3] state they help reduce the negative impacts of communication through lean digital networks. They further explain that similarities in mental models provide members with a framework to conduct the task, allowing members to predict what information is important to others. This enhances coordination among members and increases the efficiency of communication while reducing the cognitive load, all of which compensates for the communication losses inherent in lean digital networks. Shared mental models reduce the necessity and intensity of communication and still transfer the same amount of information about a task.

Several meta-analytic reviews conducted over the last 15 years have consistently supported a positive relationship between cohesion and group performance [7].

Festinger defines cohesion as "the resultant of all the forces acting on the members to remain in the group" [8]. He further suggests that cohesion is comprised of three components: member attraction, group activities (i.e. task commitment), and group pride. Results of the research done by Beal et al. suggest that cohesion is a mediator between inputs and outcomes of teams; it is a value-adding propeller of team performance [9].

Coordination has also been found to be necessary because of the usual design of teams, which are primarily assembled with individuals having different expertise and knowledge. Metcalfe and Gibson (1989), as cited by Ensign and Hébert, declared that "some coordination is necessary because specialization and division of labor implies that each individual has command of only a small part of the relevant knowledge base." [10]

In summary, we believe that for teams to function, team members must develop trust among themselves. This will lead to higher team cohesion and greater knowledge sharing. The latter, along with shared mental models, will result in high team effectiveness through the mediation of effective communication, as shown in Fig. 1.

Though not clear now, the reasons for reviewing impedances in team effectiveness will become obvious later in the paper. It is our conjecture that virtual teams in immersive worlds will be confronted with the same team challenges as are teams in tradition virtual settings. However, because of the inherent characteristics of virtual worlds like greater interactivity and telepresence, it is our belief that the factors limiting team effectiveness will be lessened in these immersive settings.

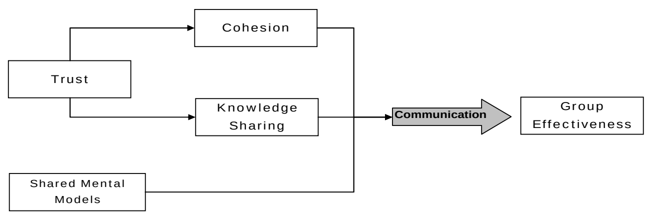

Figure 1. Group effectiveness begins with trust and shared mental models.

III. Virtual Worlds

Currently, we are possibly entering a new phase of virtual teams; one where teams are immersed in virtual worlds. One executive from a consumer research company states that competition on a global scale requires companies to search for more, new innovative ways, and that virtual worlds may add more advantage and even relevance for some industries. Furthermore, with virtual worlds, some early adopters and researchers are reporting better team performance. [11]

Virtual worlds are also known as immersive 3D worlds or the immersive internet. Virtual worlds are computer-generated places that can be experienced by many users who take on the form of avatars [12].

Virtual worlds have been rising in popularity in the early 2000's, frequently as a forum for social networking. One of

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the most prominent virtual worlds is Second Life®.

Second Life® is a 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. As of April 2008, there were 13,448,143 residents from around the globe, of whom over 65% of Second Life® inhabitants were outside of the United States. Gartner Group, a leading IT research company, has forecasted that 80% of internet users will have some sort of an internet presence in a virtual world by the end of 2011, although that presence may not but not in Second Life®, and that the users will include Fortune 500 firms as well as individuals [13].

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. As the name indicates, it is intended to provide its participants with a "second life" in which they customize and immerse themselves [14]. In fact, much of the attention paid to Second Life® has been propelled by its use of open source software, which allows 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 a value placed upon it.

With virtual worlds, organizations from various industries are exploring "in-world" opportunities they may provide. In fact, the growth of virtual worlds is attracting established companies who are interested in advertisement, promotion, and communication [11]. However, for our research interests, the scope of the remainder of this paper will be limited to the use of virtual worlds for engineering and technology-oriented organizations.

IV. 3D Environments in Engineering

Early in 2000, Jean Thilmany stated: "Within the decade, virtual reality will be the must have new technology for engineering." [15] A decade later, virtual reality and virtual presence is not as dominant as predicted. Computers have made significant changes in the way engineering work is being performed. This section will explore its early evolution and the contemporary status of virtual worlds.

A. Early Years of Virtual Reality

In early 2000, synthetic environments (virtual reality) were predicted to stimulate revolutionary changes in engineering and science. In less than a generation, designers would have gone from 2D design to immersive design whereby they can see, feel, and manipulate a product before it is produced. [15]

Early, there was a wide spectrum of definition for virtual reality, or rather different degrees of virtual reality. To some, virtual reality referred to a collection of human-computer interaction technologies that included a head mounted stereo display, glove input device, and audio. To others, virtual reality differed from the traditional visualization in that it is presented engineering designs as three-dimensional objects that could be manipulated on a computer monitor rather than as two-dimensional drawings on paper. To others, virtual reality immersed one in a computer-generated environment. The common element to all of these definitions is that virtual reality allows for a model to be a replica or abstraction of a real-life model, and it provides the user with simulated interactions that are close to real-life interaction. [16]

Nevertheless, despite the type or definition of virtual reality used, various companies were looking at how to utilize and maximize the potential of the then "new" technology. The spread of use was delayed as many other companies were reluctant to commit to a particular technology in its early stages of development.

The early 2000's actually follow the era when the technology was first developed. The use of a virtual, immersive, 3D environment can be traced back to the 1990's. One of the early virtual simulation environments was from the University of Illinois. The CAVE was created in 1992, a 3D simulation lab that was projected that it would save the manufacturing industry $735 million per year, and it was used in about 50 research centers to study hearts, enzymes, molecules, weather hazards, urban design, and automotive design. [18] Clients of the CAVE included John Deere, Ford, and the U.S Air Force and Army [15].

Companies began to experiment with more interest following the widespread availability of high-speed access to the internet. Manufacturing and engineering companies around the world began to build products virtually, enabling communication across the barriers of time, distance, discipline, and culture. Among the benefits that were interactive-product-simulation (IPS), enhanced collaborative engineering, significant reductions in design cycle time, reduction in the necessity of physical prototypes, and an increase in market acceptance and penetration of new products. These benefits began driving adoption of the practice by other companies [17]

With traditional physical prototyping, reduction in design cycle time can be achieved only up to a point. In the automotive design process, virtual reality allows the designer to "experience" a computer model and puts the "human in the loop." This can help eliminate the need for preliminary physical prototypes before a final design is selected.

Ford is one of the early adopters of virtual prototyping. In the early 2000's, Ford revealed that virtual reality software played a "significant role" in the design of their supercar, the GT40. With the software, called "Digital Occupant", Ford engineers were able to test out the car's size and shapes without having to build a physical prototype. This, they claimed, cut the number of vehicle prototypes by 90%. It also helped the engineers design for a wide spectrum of customers; as explains one designers, "I could, for example, sit in a GT as a small-statured female and see how she would interact with controls, and what her field of view would be" [19]. This capability led to decisions that allowed for more advanced prototypes in the early stage of the design process; for instance, the "first prototype was fully drivable" says a Ford engineer. Furthermore, the virtual design allowed for a shorter design cycle. Due in part to the impressive results from their introduction to virtual design, Ford announced that it would install a virtual center at its Dunton design and engineering facility to speed development and enhance collaboration between teams in Germany and the UK [20].

Another early successful application of virtual design came from the tractor designer, Terex Compact Equipment. They estimated that every physical prototype replaced by a virtual one saved £50,000. According to the engineering

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manager, “Costly design mistakes don’t happen with virtual reality, as they are spotted and rectified speedily. This is engineering design at its purest, enabling us to reduce time to market and unit cost.” This is critical in competitive consumer-focused industries. [20]

B. Contemporary Design: The Virtual World

Early adopters of virtual reality ranged from the automotive and manufacturing industries to the medical research. Over the years, virtual reality has been adopted and enhanced by the movie industry and further optimized for speed and affordability in the quest for more realistic video games. Nevertheless, virtual reality is coming full circle back to design and manufacturing. The technological capabilities have skyrocketed and the prices have plummeted as compared to the early 1990s. The technology consists of essentially the same components: gloves with more sensors provide tactile vibration feedback that gives the user the sense of actually touching the virtual object, and high resolution, high definition projectors provide immersive visual sensation [21]. Also with the advance of technology, virtual reality has evolved into virtual worlds that feature a more social and interactive multi-user dimension. With origins in multi-player gaming sites, virtual worlds re-create the social and visual dynamics and cues of human interaction, and are increasingly used in business settings. Avatars can make presentations to one another, socialize, debate, or, literally, examine ideas and 3D objects from all angles [22]. With the capabilities of 3D design within Second Life®, the medium has been referred to as an “engine of creations” [23], a “petri-dish for innovations” [24], and an “invention factory” [11].

Again, as in the 1990s, companies are converging toward the immersive worlds, in a quest to innovate their business and seek new ways to create and harvest new value. Among the early explorers of virtual worlds is IBM, which has developed a new software called Lotus® Sametime 3D®. This software allows users to hold meetings and collaborate without having to meet face-to-face. The software came from the union of virtual worlds and unified communications and collaboration tools. The software allows users to collaborate through voicechat, IM messaging, and a brainstorming wall. Documents of the meeting are available for those who have attended and need to extract some information, as well as for non-participants who wish to get a synopsis of the meeting. IBM explains, “these spaces allow participants to, literally, throw ideas on the wall during a meeting to 'see what sticks,' and to vote on, organize, and save the most promising proposals” [22]. A screenshot of two collaborators at the brainstorming wall is shown in Fig. 2 [25].

Figure 2. Lotus® Sametime 3D® collaboration uses a brainstorming wall. [25]

V. Research Question

With the “newness” of virtual worlds, little research on the engineering design process has been published to date. Most of the research is located within the social disciplines. A 2008 article formulated research issues for virtual social worlds. Questions included: What merits do avatar-based communities have over web-based communities? How will multi-organizational collaboration develop in 3D virtual worlds as compared to real-world settings? Can next-generation smart devices be developed in a social virtual world, their use modeled, functions improved, and then mapped back into real objects in the real world? Will this revolutionize the habits in which products are tested and purchased? Will we move toward “try-before-you-buy” paradigm? The questions range from social to legal to economic, which testifies to the potential richness and amount of opportunities provided by virtual worlds. It is anticipated that researchers will need to build new theories and concepts, to explore the frontiers between reality and virtuality. [11]

Among the questions posited, one is of particular interest: Why are companies investing in time and money in social virtual worlds, and what is the impact of investments in Second Life® on organizational performance in terms of sales, customer satisfaction, and retention and market share? We adjust the question and ask whether there are real economic advantages for companies to go virtual, and if so, what is the measure(s) of such advantage(s).

Cost reduction is cited as the most important driver for virtual design teams (73%), based on an inspection of the literature. However, no study of virtual teams focusing directly on cost has been found. There is definitely a reduction of cost associated with virtual teams. The focus of our research will be on virtual teams immersed in 3D worlds. Figure 3 comes from a report by Thinkbalm, an IT consulting firm based in Rhode Island, USA, and shows that organizations have experienced real cost reduction in virtual world settings. Thinkbalm’s research was sparked by requests about the business value of immersive virtual worlds in the workplace. The report summarizes their findings from a survey and in-depth interviews of 66 immersive internet practitioners, consisting of non-profit organizations, governmental entities, and corporations. [26]

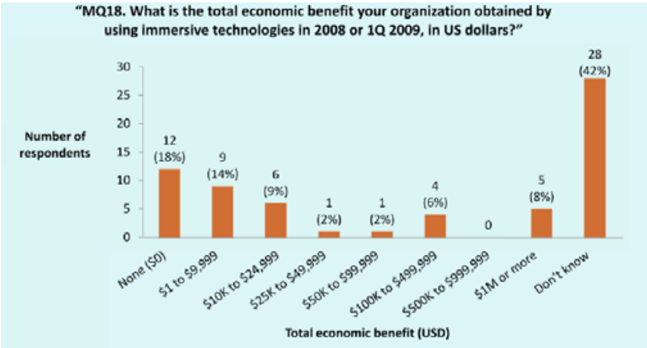

Figure 3. Estimated economic benefit from investments in virtual worlds. [26]

Thinkbalm's survey found that more than 40% of the respondents saw a positive economic return; although 42% did not know their economic. Nevertheless, over 50% responded that they predicted a positive economic return in 2009 from their investment in the immersive internet. For instance, BP expects to deliver tens of millions USD in new business value, and the company had already recovered the costs of many of its 2008 investments in immersive technology by the first quarter of 2009. [26]

It is important to point that to many the economic return of their investment was hard to quantify, as showcased by the 42% of the answered that they did not know the exact value of their return. The difficulty to measure the return on investment is also depicted by the range of the values (10,000 to 1,000,000 USD). [26]

More importantly, it is reported that due to the maturity of the technology, organizations are still in the learning phase and have yet to define a set of economic and success measures. Kelly Services responded that they felt successful in qualitative terms, but lacked the quantitative measures to demonstrate that success. According to Thinkbalm's report, this issue is common among early adopters of the immersive internet, and most organizations have agreed upon the fact that strict financial ROI does not translate the full scale of success. [26]

As such, companies have developed different metrics, which include:

•Employee productivity is one the metrics used by IBM. Each employee who virtually attended the company's Academy of Advanced Technology conference saved on average 6 hours of traveling time. Instead, over 150 people met in their immersive world; this led IBM to save an estimated $135,000US in productivity. [26]

•Increased revenue was measured for BAE systems, a company which builds and maintains a custom immersive learning simulation for the armed services personnel training. The increased revenue was measured through the direct financial gained by the volume of returning customers and by the increase in new clients.

•Increased employee retention rates. Under the philosophy that employee retention rate increases when employees are more engaged in the company culture, David Fenech [26] is using immersive worlds as what Oldenburg defined as "third places" [27]. Third Place is "a generic designation for a great variety of public places that host the regular, voluntary, informal, and happily anticipated gatherings of individuals beyond the realms of home and work [27]. Third places are where everybody knows everybody, they are also level and conversations are the main activity. Fenech's goal is to use the immersive technology to increase employee retention by creating virtual places where distributed workers can meet and build connections [26].

As said earlier, our research focus will be on quantifying the economic value of teams' immersion in 3D worlds. We suspect that virtual teams will be affected by the same barriers as those in traditional settings. As such, an important question is whether potential cost reductions outweigh the intangible costs incurred through the friction that may come with virtual teams. A systemic approach to developing the cost structure will identify both tangible and intangible cost drivers. Once the latter are understood, it should then be possible to implement more cost effective systems.

Four areas of cost drivers are immediately evident: personnel, material, infrastructure, and product related costs. These costs are mainly tangible and should be straightforward to measure. On the other hand, there are many costs and benefits from virtual teams that are difficult to describe and may be immeasurable. These are intangible costs associated with the problems encountered with virtual organizations, such as cultural barriers and lack of trust. These costs manifest mainly in the delay in time and productivity that they cause in the system. Among the immeasurable yet important benefits of virtual teams is the increase in team productivity, innovation, and motivation. There is also the potential benefit of having a product first to market as by reducing of the product design and development cycle time.

The tangible costs can be directly measured using actual data. Metrics for intangible costs will be developed using the balanced scorecard method. Once these have been defined, surveys can be conducted to gather data for analysis. Analysis of the results of overall model can then provide for improvements to the model and assess its validity. This will then lead to an independent tool by which organizations can measure the effectiveness of their virtual teams.

VI. Conclusion

Virtual teams are quickly becoming a standard organization structure. Virtual worlds have evolved into both social networks and immersive environments in which to conduct business. The tangible and intangible costs and benefits associated with virtual teams, especially those in virtual worlds, have not been thoroughly studied to date, thus further work is needed.

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