Abstract – With the emergence of globalization, engineering firms as well as engineers that work in those firms are faced with new opportunities and challenges. Recent globalization has led to new work roles for engineers. Whether formally or informally, an increasing number of engineers are now playing the role of boundary spanners and are brokering knowledge across geographic boundaries. In this paper I present a case study to identify the requirements and characteristics of this role. The data for this paper comes from two sources: selected interviews with software engineers and an ethnographic study of a global engineering R&D firm. The informants represent the U.S., Japan, and India. The findings show that agency of workers in the midlevel of the organizational hierarchy drives successful global practices. Moreover, given the dynamic nature of work in the present knowledge economy, the requirements of this role keep changing. In addition to skills such as working across time zones, using technology effectively, and developing interpersonal networks, there are additional tacit aspects of this role that can be learned only through participation. I present and analytical model and discuss the relevance of these findings for preparing engineers for the global workforce.

Index Terms – Global work, boundary spanning, knowledge broker, engineering practices, information and communication technology

INTRODUCTION

Geographically distributed work has been around for centuries [1] making globalization and concerns with global trade a recurrent theme of scholarship. Recent advances in technology though have reshaped the extent and nature of distributed work and an increasing number of people now work as members of global or virtual teams with coworkers who are dispersed across states, countries, and continents [2]-[5]. These changes have had contradictory affects. On the one hand they have brought people together to solve significant problems and on the other hand they have led to increased interpersonal and organizational breakdowns [6]. Geographically dispersed workers lack mutual knowledge and common ground leading to misattributions and breakdowns in communication and collaboration [7]-[8]. They also have greater interpersonal conflict [9]-[10] and lack of trust [11]; they are prone to subgroup formation [12] and ethnocentrism [13]; and, find it harder to share knowledge and expertise sharing [6]. In spite of these problems globalization of work practices is on the increase and there is a rise in industries and functions now being done across the world. How does one make sense of this seeming contradiction? One explanation, often found in the popular press, is that cost arbitrage, or the significantly lower cost of doing work in another country, drives increasing globalization, and in some cases outsourcing, and therefore firms force workers to engage in distributed work. The other argument is that as workers learn to work across their differences they learn to innovate and be creative, significantly affecting the design and distribution of engineering products [3]. So, the question becomes: What are these differences that workers need to overcome? And, how do they do it? What are the mechanisms for the actual “doing” of the work? In this paper I argue that individual agency – the effort, struggles, and initiatives of workers – leads to successful global work practices and has even resulted in a new work role for engineers that of “boundary spanning knowledge broker.” In this paper I draw from empirical data to examine what this role involves, especially from the viewpoint of engineers. Before examining the empirical data, I briefly review prior work to lay the foundation for discussing the data. Both the literature review and the empirical arguments presented in this paper are necessarily short given the logistics of a conference paper.

BOUNDARY SPANNING

With the rise of the global economy and knowledge work, the structure of organizations is changing. From a rigid hierarchical structure, organizations are moving towards a network based structure and this has given rise to informal boundaries and opportunities for people to bridge or span these boundaries [14]. As Wenger [15] reminds us, “boundaries are at once unavoidable, necessary, and useful, even though there may be specific cases when they need to be crossed, rearranged, or even dissolved altogether (p. 290)” and when engaged in a meaningful manner, boundaries become tools that facilitate and support sensemaking. Within the context of globally distributed work, the boundaries are not only cross-functional but also locational, temporal, and relational boundaries. In instances where virtual teams overlap multiple relational networks, members have to work through different frames of
reference, motivations, knowledge domains, and work styles. Moreover, mutual knowledge and common ground are essential to team functioning and have to be developed and repaired for effective functioning of global teams [7]-[8]. Consequently, one essential role that emerges is that of boundary spanning and this involves knowledge brokering – transferring and sharing their knowledge about one location to another.

**KNOWLEDGE BROKERING**

Knowledge brokering [16] involves bringing people together creating new relationships and sharing of ideas that can enable workers to perform their jobs better. Essentially, it is the human face to the process and idea of knowledge transfer and underlines the agentic nature of this process. Although knowledge brokering can occur even without individuals dedicated solely to the process, they are a critical component of the process, it requires effort from them. In many workplaces brokering is an ongoing and largely unrecognized and unplanned activity. Yet, in distributed teams, due to lack of mutual knowledge among distributed members, there often has to be a concerted effort to recognize and formalize the work.

**STUDY 1: GLOBAL SOFTWARE ENGINEERS**

For the first preliminary case study, I interviewed 4 software engineers in depth about their experiences as members of global teams. All the informants were of Indian origin and had worked both in the U.S. and in India. At the time of the interviews they were based in the U.S. The informants had worked with other engineers in the U.S., India, Japan, and Sweden. The interviews lasted between 1-2 hours and were preceded and followed by informal communication. In addition, I had frequent overall interaction with the informants and therefore knew about their work. Although all informants were engineers, the undergraduate background of the informants was diverse and included electrical engineering, electronics and communication engineering, and mechanical engineering. Within the context of the larger software industry they worked on different platforms as well as vertical domains including JAVA, mainframe, mobile, finance and energy. At the time of the interview all the informants had a bachelor engineering degree and had been in the industry for 7-8 years. Each informant had started as developer and now their position varied from team lead, technical lead, to associate. Overall, they all had reached a position that I define as a boundary spanning knowledge broker. They all had different experiences in that position. Some were grappling with it, some had problems performing that role, and one was quite successful within that position.

*I. Amit – Where do I start?*

Informant Amit, based in the Silicon Valley, was one of the firsts to draw my attention to the morphing of roles in the industry. Although from my professional experience I had seen these changes as well, I was not consciously aware of the difficulties now facing global workers. Amit had been working for 3-4 years and had been part of a global effort. But his earlier efforts were about getting a specific plan from the client, developing the product, and then delivering and deploying it. Although some interaction was needed after that stage, it was minimal. This changed as clients wanted more country specific products as well as a relationship that could be harnessed for longer. Therefore, Amit was told to head a team of 3-4 developers and work closely with a client on a critical product. When I interviewed him he was completely at a loss as he had just been told about his new position and was given minimal direction. When he asked his superiors about this function he realized that even they had no idea how to go about starting this out. The position was in some ways informal and in a way it was still being formed. Therefore, although at the firm level there was a consensus that a new kind of role had organically emerged there was no agreement on the nature of that role. He realized that he will have to learn through a trial-and-error process and even though this did not start out too well for him over the next several years he fit the profile well.

**II. Nitin – A Successful Transition**

Having worked in the U.S. for a client for almost 4 years, Nitin was asked to help them with their overseas office in India. A chance occurrence placed Nitin in the newly formed office of the firm in India for 6 months. During that time Nitin not only learned what the job of a knowledge broker entails but how to perform it successfully. While in India, Nitin developed interpersonal relationships with newly hired developers, taught them about the systems used in the U.S., and learned about their context of work. While in the U.S. he was able to use his network to his advantage by making his team a lot more efficient compared to other teams. Of course, he also had to change his work habits to work in concurrence with the Indian developers. For instance, on a particular day I observed him talking to his team at midnight U.S. (EST) time, when they got to work, and then he woke up early to talk to them once again before they left for the day. Since he knew the context of work in India – all developers had to come by bus and leave by bus at a specific time – he made sure to change his work environment to fit theirs. He was able to do the late night and early morning conferencing from his home. When I asked him about this he said that he had to change the way thinks about 9-5. Now he has to do his errands preferably during lunch, which he can extend, and work around India time.

**III. Alok – Socializing to Work**

Alok worked in a small start-up at the time of the interview. Previously he had worked in a larger firm and after working in the U.S. for a few years he was asked to head a small group of developers in India. Even though he had prior work experience in India overseeing this team turned out to be a lot more complicated than he had expected. This was one of the reasons he had left his previous company to work in
start-up that he knew was local. But during his tenure there the start-up bought a small firm in Sweden and Alok had to start working with colleagues there. He decided that since global work was becoming a norm and there was no escaping it he will try and make the new collaboration work. Moreover, he decided to become a broker and during the visit by Swedish coworkers to the U.S. he deliberately socialized after work. He argued that the best way to learn about the context second had is to have drinks after work and this also gives the other side to learn about you besides your work settings. Nardi & Whittaker [17] have argued that such face-to-face meetings are critical. Moreover, [18] has showed that in addition to face-to-face traveling gives the distinct advantage for being able observe and interact with other in diverse settings leading to more complex and useful impressions [19]. The knowledge broker takes advantage of this and gets to understand the boundaries and then figure out how to span them.

IV. Sanjay – Changing Dynamics

The work of a knowledge broker is ongoing as the dynamics of a global team as well as the institutional and organizational constraints keeps changing over time. This aspect was highlighted by Sanjay in his interview. Sanjay had been working for outsourcing service firms for almost 8 years and therefore had seen several phases of the transformations. He started out as a software engineer and became the manager brokering knowledge between clients in the U.S. and India. Although he spent some time India for the past 4-5 years he had been at different client sites in the U.S. He said that the initial dynamics is such that the knowledge resides with the client and therefore the knowledge and expertise about the “system” i.e. domain knowledge has to be transferred to the developers. Therefore more power resides with the client and less with the developers. Over time the developers take control of the system and then there is shift in power. The client now is more interested in improving the system and providing more value to its customers and therefore she works more in collaboration with the developers. All through this process the knowledge broker has to understand the overall situation and phase of the relationship and the shifting boundaries and work to make things better.

STUDY 2: GLOBAL R&D – TECHLAB

The field site for the second case study was a research and development laboratory with offices in the U.S. and Japan. I will call the laboratory TechLab. TechLab is the R&D division of a Japanese multinational which I will refer to as TechCom. TechLab conducts research in the area of hardware and software information and communication technologies with expertise in information management and media systems. At the time of this study TechLab had entered its 10th year as a research lab. TechLab had around 20 fulltime researchers in the U.S. and around 50 fulltime researchers in Japan. In the U.S., its researchers were supported by an additional staff of about 20 people that handled the administrative as well as technical support responsibilities. In addition to developing technologies, researchers engaged in activities such as publishing and presenting papers, and filing patents. The primary data collection for this study occurred at the U.S. site of TechLab. At the site in Japan purposive sampling resulted in interviews with all researchers from a specific group and researchers who were identified as having significant collaborations with researchers in the U.S. I used an in-depth qualitative field study and data were collected using interviews and observations, supplemented by field surveys and archival materials. I spent a total of 5 months at TechLab. I formally interviewed 47 individuals for a total of 70 interviews. In addition to the researchers I interviewed technical support staff, administrative staff, and interns. The informants were observed at their place of work. All interviews were transcribed verbatim. Observational field work was undertaken for 80 days and I was at the site for 5–8 hours each day. The relatively small size of the organization facilitated in-depth look at relationships. Overall, interviews and observations resulted in around 1500 pages of single spaced text.

I. Formal Brokering

At TechLab knowledge brokering was seen as an essential part of organizational function and therefore there was an official position created for this purpose. This position was also considered essential given the challenges due to different languages at the two locations. Business at the U.S. location was handled in English and in Japan in Japanese. The role was primarily administrative in nature and was held by a Japanese expatriate employee of the company. I interviewed two people that held this position while I was doing my field work. Both were engineers and had extensive background and tenure with the firm and had been with the firm for 15-25 years. Initially they had started out working on hardware technology within the firm and had moved their way up and across functional areas. Cross-functional experience worked to their advantage and as one informant noted, “Nobody had experience [with] the process of productization or including quality assurance. And so, I was asked to organize that group and set the new standard for that.” Their prior experience with being able to bring together different functional areas worked to their advantage for getting this position as well as to their performance.

The daily work routine of the informants included frequent meeting with their U.S. colleague and meeting with Japanese colleagues. They had to stay up late and often make calls late at night. They helped their U.S. colleagues in several ways. They gave them contextual information before travel and prepared them with the travel. They arranged meetings with Japanese colleagues and this was quite critical. Often the U.S. colleagues had an idea or specific problem they needed help with but often did not know who worked on that in Japan or how to even contact them. Therefore, the responsibility fell on the informants to
and observe directly how he performed this role. My first
trip was with one U.S. researcher to the Japanese location
and it was evident through such interactions that many
strong relationships and increasing their interpersonal
network were directly in touch with them. They also spent
time socializing across locations. The process started
when they identified a specific need – often technology
exchange – that necessitated traveling. When they
traveled to the other location in addition to spending
time with the person they wanted to meet, they also
spent time socializing and increasing their interpersonal
network. Without oversight from the management many
strong relationships formed through such interactions.

One critical organization level issue that the informants
helped with was in syncing the temporal nature of work. For
instance, the tax cycle in U.S. and Japan is different.
Therefore, all annual reports are due at a different time
then in the U.S. annual cycle. Moreover, they knew about
other internal cycles such as monthly project deadlines,
review meetings, and so on and they helped keep the U.S.
colleagues on track. Although this sounds mundane but has
huge implications for distributed work. For instance,
attention by U.S. colleagues to build partnerships with Japan
often failed and the U.S. researchers thought that the
Japanese colleagues were just not interested in their ideas.
It was only after a while that they realized that this was not
case but their timing was not right. By the time they proposed
something, the Japane se colleagues had already been
working on something else for a while. Interesti ngly,
engineers had moved into these positions as an understanding
of the underlying technology was seen as essential.

Although a positive thing on the whole, there was a
downside to formal brokering and that was gate keeping.
The brokers realized that they had power and they often
used it in a way that was not beneficial for the organization
but for themselves or their close network.

II. Informal Brokering

In addition to the formal brokering role, TechLab had many
workers who performed this role informally. Their need
to broker knowledge across boundaries grew from their
personal needs and experiences. These workers were either
from the U.S. office or Japanese offices and often traveled
across locations. The process started when they identified
a specific need – often technology exchange – that
necessitated traveling. When they traveled to the other
location in addition to spending time with the person they
are directly in touch with they also spent time socializing
and increasing their interpersonal network. Without
oversight from the management many strong relationships
formed through such interactions.

While I was doing my field study I got the opportunity
to travel with one U.S. researcher to the Japanese location
and observe directly how he performed this role. My first
hand experience made me realize the effort and time it takes
to play this role successfully. This researcher, I will call him
Dave, had developed a product which was oriented towards
industrial clients and he realized that the Japanese market
might be attracted to this product. Therefore, he realized that
it was essential for him to develop stronger relationships
with colleagues in Japan that could serve two primary
purposes – help him with the development and help him
introduce the product to other cross-functional departments
that dealt directly with marketing. As I met with him before
the trip he was busy working on the planning for the trip,
arranging and scheduling meeting, and making a list of
topics that needed to be covered. His schedule was back-to-
back meetings for almost the entire week. Since he was
meeting with workers other than the team he was directly
working with he had to do background research on all of
them and prepare rough notes about what to talk about. Plus,
he was also temporarily the manager of a research group
and had to meet all the counterparts in Japan. He had to
reflect on the meetings and make a list of future to-do items.
At one point during the trip he was so tired he said to me,
“One week and then I’m ready to head back home.” When I
asked him what made him take on this role, as it was really
not required, he said that diversity and access to market was
critical for innovation and if he wanted to see his research
effort be fruitful he had to form interpersonal relationships
with Japanese colleagues to help him with his goal. He also
said that the perspective that the Japanese researchers
brought was often useful in thinking about things in a new
way.

Whether formal or informal, brokering was critical to
the functioning of the research lab. Given the different
institutional and organizational environment, and the
physical setting of the labs, it was essential for workers to
understand the context of the other location. The brokers
realized the similarities and differences and often talked
about this in their interviews. For instance, the Japanese
office was in the suburbs and most workers lived in the city
requiring commute by train and by bus while U.S. workers
traveled by their personal vehicle. The Japanese informants
often commented how hard this made it for them to come
really early or stay late to have a meeting with their U.S.
colleagues. Initially many U.S. researchers were surprised
by the reluctance of their Japanese colleagues to meet for
teleconferences. They were also surprised by scheduling
problems and that many Japanese colleagues were often late
for videoconferences. One U.S. researcher explained to me
that the reasons for these problems became evident to him
when while he was in Japan for a visit he decided to sit it on
a videoconference with his U.S. coworkers to get the
experience. He realized that there was only one
videoconferencing facility which was shared by almost 3
times the number of workers and given the distance between
offices in the same city in Japan, the videoconferencing
facilities were used even more. Also, he realized that the
facility was some distance from where the workers had their
cubicles and it took them a while get there. Therefore, if they were running between meetings, they were often late.

Knowledge essential for brokering was accumulated over time and it often involved several trips or an extended stay to understand the different nuances in context across locations. Moreover, forming interpersonal relationships was even tough and required frequent communication and follow-ups. Once formed, these networks were quite stable over time and even after workers had stopped working on a project they still helped each other out with cross-location problems and issues. Informants also used their distributed networks to help collocated coworkers at their site and this was especially useful for newcomers.

CONCLUSION
To summarize, I present the basic argument of this paper in form of a model (Figure 1). Geographic dispersion of work creates several boundaries including distal, temporal, and disciplinary. Although boundaries exist in collocated work practices as well, geographic dispersion introduces additional barriers to working across boundaries as informal interaction and common ground are absent. Therefore, working across boundaries requires individuals to put in extra effort. This necessitates increased use of interpersonal network coupled with the use of technology. Of course, the knowledge broker first has to develop the network which often involves traveling and judicious use of technology. Once formed, the network is relatively easy to sustain but it still requires frequent and regular interaction.

In terms of the ‘output’ of knowledge brokering, I argue that the end point is an “alignment of perspective.” In other words, a knowledge broker attempts to bridge frames of references which often differ across locations [18]-[19]coworkers have different lenses through which they view things. Therefore, boundary spanning involves developing common lenses to look at tasks and artifacts and work jointly on them. The model presented here is simplistic in some regards as it fails to take into account dynamicity of the role of a knowledge broker. As several informants responded in their interview, the boundaries change and shift with time and brokering involves collecting feedback, reflecting on experiences, and recalibrating how the role is undertaken.

DISCUSSION: PREPARING ENGINEERS
I. The “Post-modern” Engineer
In this paper I have discussed how a new role is emerging in global engineering firms and examined the characteristics of this role in-depth. Kakihara and Sorensen [20] identify this as post-modern professional work. This role requires engineers to possess skills that often go beyond their training in the undergraduate or even the graduate programs. Often, these skills are learned “on-the-job” but the failure rate or the chance of getting frustrated is quite high – as experienced by Amit. Although the role of a knowledge broker is becoming increasingly recognized and institutionalized within firms, as reflected in the interview and observation data, a lack of a coherent set of characteristics that can easily define this role makes it hard to teach how to undertake this role. Knowledge brokering involves a multitude of things and the boundaries are also numerous. Moreover, there is dynamicity to the process where the needs of the role and the context in which the role is performed keeps changing. This raises the question of how do we prepare future engineers to be able to perform this role?

II. Preparing Engineers for the Global World of Work
There are several approaches that can be adopted to prepare future engineers. But overall, the best solution might be a

![Figure 1: Boundary Spanning Knowledge Brokering](image)
combination of things. There are specific skills that students need to learn such as being able to work effectively with technology, managing time differences, skills with languages, documenting skills, and travel experiences, but in addition to this they need the ability to reflect on their experiences. One form that the solution to this problem takes is of teaching students about other cultures. Although useful, this is not as helpful since this is only the first step in the learning process – being aware of the differences. Students need to move beyond that and learn about the emergence of boundaries and being able to recognize them in the dynamic environment of global work. Several classes provide first-hand experience with this problem as well. For instance, students work on group projects with students from other countries, often for an industrial partner. This gives them first-hand knowledge about at least some of the issues such as effective use of technology and working across time zones. This also provides the opportunity to expand their contextual knowledge at least to some degree [21]. Another avenue might be the utilization of adaptive expertise based curricula whereby students are provided some experiences combined with case studies that test their skills in different scenarios [22]-[23]. With increasing globalization of work over the past 2-3 years many firms are advertising for positions that specifically ask for workers with expertise in global knowledge brokering, even though they might not call it that. The difficulty for firms and for applicants still remains the lack of access to training they might not call it that. The difficulty for firms and for applicants still remains the lack of access to training. For workers in these roles, the world is not all that flat [24].

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