A NSF CAREER PROPOSAL PRIMER
Aditya Johri

My junior colleagues often ask me for advice on submitting a proposal to the NSF Early Career Award solicitation and as it has now been a decade since I submitted and received my award I thought it was a good time to reflect on my experience and put some of it in writing. My CAREER award was funded by the EEC division within the Engineering directorate so my thoughts are probably more relevant to those who are applying there but I think they might be useful in general to other awardees especially those who are submitting educational research related proposals.

As with most funding agencies, NSF has its own quirks and for a proposal to get funded it must pass muster with a review panel. This can seem daunting. It is challenging and I'm especially reminded of this when a proposal of mine does not get funded. There is no doubt that NSF funding is extremely competitive, and is becoming even more so with every passing year but here is some advice worth keeping in mind. Sue Kemnitzer, who was the PO who funded my CAREER and several other initial awards, used to tell new PIs – "you're only competing with 33% of the proposals." What she meant by this was that of the proposals that come in, almost a third are not even in the competition because they have either submitted to the wrong program or wrong directorate or the PI just resubmitted a proposal that was recently rejected from some other panel. In other words, they are giving it a blind shot which is not likely to work. The other third have written a good proposal but they have missed a critical element that will quickly be called out in the panel and make them uncompetitive. The real competition is between the proposals in the last pile and it is here that you need to stand out if you want to have a chance. This is does not make it easier but eases the panic a bit when you realize that you are not truly competing with every proposal that is submitted.

I submitted my CAREER proposal in the summer of 2009 and I received the award on the first try. This, of course, is the narrative even I've come to believe but as I was going through the folders on my computers I found a folder titled "CAREER 2008" and in there was a very rough draft, merely ideas, of the proposal I eventually submitted. So, in reality, I started working on my proposal at least a year before I finally submitted it. I don't recollect why I didn't submit the proposal in 2008 but I'm one of those people who don't submit a proposal until I feel it's really well done.[1] And maybe, I'm just slow. The likely reason that I did not submit it in 2008 is that I thought that just putting all the pieces together for the proposal – collaborations, advisory board, etc. – would take so much time that I won't be able to write a good proposal. Yet, the primary ideas survived in the next year's version. And in the meanwhile I was able to get feedback on a complete draft, get access to research sites, put together and advisory board, test my preliminary ideas, and do all the other things that I believed were necessary to submit a convincing proposal.

If you are thinking how much time you need to write a good proposal I don't really believe that there is an ideal time frame. I know folks who have been successful with a month of effort and I know folks who took all three attempts before they finally got it funded. It all depends on how comfortable you are with the writing and with putting all the pieces together and whether you are someone who prefers to let ideas marinate or who gets inspired in the moment and needs to get done quickly. It also sometimes depends on timing – some ideas seem more urgent in a given year than others. It also depends on the pool and who else has applied. In other words, on factors that are not in your control. So, you should apply when you feel you are ready. Sometimes it helps to talk to others about your ideas and approach and get feedback on whether someone reading your proposal would also get the sense that you are ready.

[1] I'm aware that this is not an advice that most people give or receive but I stand by it. At least I've never been successful with a hastily crafted proposal.

All it Take is a Brilliant Idea

We are told in relation to the CAREER proposal that a good idea is the crux of the proposal so let's start there[2]. A good idea does not mean any good idea. We are members of an academic community and within that larger community we are often trying to contribute to a narrower topic and therefore the research idea has to be able to contribute to the discourse within the community. If you cannot talk about your idea in relation to the discourse in your community or connect it in some way to the scholarship in your field or discipline, the "goodness" of the idea in terms of novelty or impact is of not much utility. This, of course, is not an invitation to jump on the fads bandwagon within the field but to look towards making a deeper and long-lasting impact within the academic community.

You also have to keep in mind that your proposal won't be submitted to NSF in a universal sense – it will be submitted to a specific directorate, division, and program and more often than not a specific program officer will be responsible for getting it reviewed. These are pragmatic issues and one must pay attention to them. Of course, one should not fall into the trap of thinking too much about them and not enough about one's ideas but being able to balance ideas and submission is critical not just for the CAREER proposal but even otherwise for long term strategic thinking of one's research portfolio and agenda.

In terms of my proposal, which is appended to this document with comments, when I thought about an idea I didn't just come up with something from thin air. It was something that was important area within the field and also something that linked directly with my dissertation work.

Why You?

The reality of the CAREER award though remains that it is an award that is reflective of the PI as much as it is about the idea in the proposal. There is a good reason for that. The idea behind the award is to build the research community. To ensure that early career researchers get a boost at the start of their careers and therefore it becomes about the PI. Therefore, one has to keep in mind why it's them and not someone else that should be funded to do work on that particular idea. The idea-investigator fit is crucial. This is where connection with your prior research, work experience, outreach efforts, and other aspects of your experiences comes into play. You need to make that connection for the reviewers.

The CAREER proposal is just one step towards what is going to be or is expected to be your long term agenda and it is the responsibility of the PI to be able to articulate that and convince the reviewers that it is a good fit. This means being able to make the proposal about not just proposed and future work but also about the PI's background. There are of course exceptions to this and many researchers have been able to move from their dissertation work to completely new areas, especially within engineering education, but this is not a typical case and even within engineering education is not that common anymore. When the field was new, it was often expected that those from other disciplinary backgrounds would make their way into the field but with a critical mass now, a strong background in engineering education is expected. There are enough reviewers now within the field to be able to look critically at a proposal and gauge whether it will have an impact.

[2] What I always ask myself and often others is a bad idea? It's equally hard if you think about it to come up with a bad idea as it is to come up with a good idea. What I mean by this is that any seed of an idea can be massaged to appear good and vice-versa.

Crafting the Proposal Narrative

Once you've an idea you like and you think fits with who you are as a scholar and once you've identified where it is going to go, what next? Now comes the hard part of crafting a narrative that convinces the panel that this is great idea to put money behind and you are the best person to do the work. Always remember that as you work on the proposal your ideas will get refined and you as a researcher will develop over time as well so the idea-investigator fit will keep changing. This is fine. The initial groundwork is to create scaffolding for the proposal.

The proposal itself has the standard sections that are expected of this genre. They vary based on the specific disciplines in terms of what is covered and how much coverage each topic receives but I've always believed that it is a good practice to stick with the standard genre of proposal writing – sections on theoretical or analytical framework, methods, etc. – largely to lower the burden on the reviewers who have to read a lot of them. They have certain expectations and there is no good reason to surprise them by playing around with the format – do that with your ideas (domain, research methods, application, and/or dissemination). Tell them what you are going to tell them, tell them, and then tell them what you told them. It is not a detective novel or suspense thriller so be clear, concise, and comprehensive from the get go. Impress with both depth and breadth. Having said that, if you can add a few small pieces to make your writing refreshing or different from other proposals, do so.

Whither Theory?

What is theory? It is a way to frame your contribution, first and foremost. Theory here is not "theorem" as is used in the physical sciences and most of what we have to say about the world is socially constructed regardless of how much quantification we do and what kind of analysis we undertake. In the current culture, words are all what we have and there is only so much precision you can get with words. The precision that does exist comes from the way in which words are used within the discipline or field. Theory, as I've written about in other venues[3], serves the important function of telling us where you belong within the different traditions that comprise your field. It helps one understand where you think your contribution might lie and if it is an important contribution. There are other ways to argue for contribution. Often you can do it in terms of content – discussing an important topic – which is fine but it doesn't tell us how you are going to incorporate what came before and provide guidance for how to take the work further. This is what the research enterprise is about. Keep in mind that reviewers have different levels of dogma when it comes to theorizing and what theories you use or contribute to. This is where your literature review and research questions or hypothesis need to guide the reader of your proposal. Why this theory and not another? How does it serve your purpose and how do you serve it in return?

Engineering education in itself has not done much theoretical contribution as a field and has instead relied on incorporating theoretical work from other social science field. This is not uncommon in education overall. Most of educational research has relied on theoretical work in psychology or sociology. What has changed now is the interdisciplinary nature of work that is becoming more prevalent and therefore there is a higher burden on the proposer to make a case for why they are drawing on the theories they are. Not every reviewer will be aware of the theoretical framework you use and the fit needs to be clear. Increasingly many fields that rely on interdisciplinary work are plagued by what is being called "theory-fetish" – the unreasonable expectation that every piece of empirical work needs to extend theoretical understanding with very little practical implication. So, I

[3] Johri, A. (2010). Creating Theoretical Insights in Engineering Education. Guest Editorial, Journal of Engineering Education, July 2010.

think a cautious approach is advisable where theoretical contribution is valued but not at the cost of also making some practical contributions.

Fullproofing Methods

Methodological aspects of your proposal are often the one that get critiqued extensively in review panels largely because it is easy to attack the methods section and because reviewers often come from very different traditions. A lot of ink has been spilled in the engineering education literature on methods and I really believe that there is no way to have a fullproof methods section. Therefore, rather than wasting too much time on trying to cover each and every aspect of the methodology you wish to use, it is better to make a strong case for how your methods link to your research questions or hypothesis and to the prior work that supports that approach. This does not mean you should not be comprehensive in your discussion of methods but that there are always limits and reviewers who have actually ever done any research know that there are plans and then there is the reality of doing research. What you want to convey is that you've thought through your research plan and it serves your purpose well. What is important is to convince the panel that you've the expertise and the support to undertake the research. If you need research sites, line them up. If you need to work with a specific population, make sure you've access and permission. The "do-ability" of research is more of a concern than the actual methods.

Overall, the ability to write a convincing narrative for why you want to use a certain method will serve you well beyond just the proposal. It's a good exercise. It keeps you honest. My CAREER proposal was largely qualitative research and given my questions it was the best way to get the requisite data. I did end up doing some surveys to support the qualitative work but that was because of the nature of access and the need to give actionable feedback to the firms I was working with. I was always more concerned with actually being able to do the research as I had previously done large-scale qualitative research with engineering firms and I knew all the challenges that came with kind of work starting with access.

What – Only 15 Pages?

Like any other venue, NSF proposals require you to pay attention to specific elements of a research project and it is important to cover all your bases in the proposal. Even though 15-page limit does not seem like a lot of space, it is. The page limit works both ways, it constraints you but it also allows you to be creative. It forces you to be able to express your ideas in a concise manner and use visuals, tables, figures, charts and other representations to get your ideas across. It is important to do this in a manner that best supports the overall objective. I don't have any secrets to writing the proposal but one of the ways in which I use the 15 page-limit constraint is to help me outline the proposal. I divide the 15 pages into ½ page sections giving me a total of 30 sections and then for each topic I want to cover I assign it multiples of ½ pages. It's an idiosyncratic process with no real rationale behind it but like any similar process, it serves a purpose. It provides me with a mental model. I also develop an overall flow chart of sorts depicting each section and look at the overall flow. Once again, this is something that works for me but is not necessarily the way you might want to work. The important thing is to be able to have an overall high level view of the proposal but also outline it at a micro-level to ensure that different elements tie into each other and the narrative flows naturally. It allows me quickly check if everything I wanted to cover has found a place in the proposal.

Always keep in mind that not everyone who reviews your work would be an expert in your domain. That's the whole point of multiple reviews. Therefore, what you write needs to reflect how your project serves multiple stakeholders. This doesn't mean that there is no depth but that the onus is on you are the PI and the writer to convince the reader that your work is worth funding.

Advisory Board

The requirement to have an advisory board or not and even to have an external evaluator or not varies significantly based on which division one applies to within NSF. Given the budget limits, it is hard to actually carve out funds to pay for evaluation and/or advice except, maybe, for a token honorarium. Yet, I found the exercise of putting together an advisory board quite helpful as it made me think about the expertise that is needed beyond what is already available. I had five people on my advisory board, some from my institution, some external, a mix of academics, administrators, and industry experts. One thing to keep in mind is that anyone who is on the proposal in any capacity automatically becomes a 'conflict of interest' for the purposes of reviewing your proposal and in some cases that entire institution might become a conflict. So it is important to be careful in putting that group together.

Dissemination

The idea behind asking for a dissemination plan is really to get one to think beyond the obvious – publications and presentations at conferences. Once again, this requirement depends on the division at NSF you apply to but for EEC the ability to take your work beyond the academic research community and towards practice is important. The research EEC does is in the service of improving engineering education in some way shape or form and therefore it is natural that you should think about it and be able to articulate how you would go about doing it. Workshops, tutorials, online presence, editorials, columns and commentary, are all valid ways and so is implementation in courses, or institutional change through outreach. Social media is another creative way to get ideas across and also create a network of folks who might be interested in your work.

Budget

Budget is an ever changing parameter especially given the indirect rates charged by institution. Just in the last decade, a $500K budget gets you what a $400K budget used to and in many institutions even less. (Yes, I too wish that faculty salaries increased proportionally!). The CAREER budget is never enough to hire more than one graduate student. Therefore, plan accordingly and get ready as a PI to do substantial amount of the work yourself. This should also make you alert to the fact that you need to use your CAREER award as a spring board for other projects to keep your research trajectory going. When putting together the budget, make sure to account for all the small things. Recorders for interviews, software for analysis, transcription costs, travel, advisory board, gifts for participation, and so on. Personally, I always viewed my CAREER award as a springboard for other ideas and as I conducted my field research I did get new ideas that I submitted as proposals.

Getting Feedback

Needless to say, being able to get feedback on your proposal during the writing process is invaluable. There are different stakeholders you might want to get feedback from. It is always a good idea to run your idea by your NSF PO. They know what is in the pipeline, they know what is current, and they know if something is feasible or not. This does not mean they can or should give you a "yes" or "no" but just the process of discussing your idea and being able to articulate is a good thing to do.

It is also a good idea to talk to colleagues in your school or college, even though they might not be in your area specifically, and then those who know your work or do similar work. Of course being able to talk to previous CAREER winners helps tremendously but it is not a requirement for getting meaningful feedback.

In my case I attended several workshops on writing NSF proposals at FIE, ASEE, and other conferences/workshops and also at my own institution. One of the most useful outcomes was that the institution I was in asked other CAREER winners to share their proposals and even when they were from a different field, it was useful to see how they were constructed. I also searched online and was able to find many successful full proposals that awardees had posted on their websites. One of the awardees had posted examples of both successful and previously unsuccessful proposals and comparing that was useful. These help because you can see the common denominator – what is it that everyone makes sure to cover? What are the obvious items that need to be there in the proposal and you might have overlooked? Online search was also useful in uncovering documents with feedback from other CAREER workshops[4].

There is getting feedback and then there is incorporating feedback. One thing you learn over time is how best to incorporate the feedback you are receiving as not everything you learn in that process is going to be relevant or useful for the proposal you are working on at the moment. Feedback will often be contradictory. You are in the best position to take what you are getting and weigh its merits. Your proposal can't be a dump of all the ideas you receive otherwise it will lack cohesiveness. It is also no use receiving feedback and not taking it into account just because you don't like what people say or you disagree with them. The art of using feedback is in keeping your ego aside, looking at your work from the perspective of an outsider, and then making changes to it so that it reflects the best ideas you get.

Getting the Grant

The year I got the award was a strange year for funding. There were additional funds to support research at NSF through the ARRA (post-recession bump) but they came with a lot of strings. I had to reduce my budget which meant I had to re-scope the project. I could not ask for extension nor could I get supplements on the project. This is usually not the case with CAREER awards – supplements are usually generous – as the initial budget is limited. So that is something I had to keep in mind when doing the research.

"Doing" CAREER Research

The advice that is sought of me is largely about constructing a "winning" proposal yet what I have learned from my experience is that managing the award once you receive it as much a challenge, if not more I know those who are still in the application process don't want to hear that and possibly don't even care, which is fine, but I believe that knowing the realities of actually running a project make for a stronger proposal because the reviewers for the most part know the challenges involved and appreciate a proposal and PI who has thought through what the project actually involves.

The most challenging part for me about actually doing the research I wanted to do was to get a good team together i.e. recruit students who would be interested in the topic and could be trained to do the work. I was a in a relatively new department with a brand new doctoral program and it was hard for me to get students to work on the project in a dedicated manner. By that I mean as their dissertation topic. Project work had to get done and so through a combination of undergraduate, masters', and doctoral students and eventually a postdoc, I was able to undertake most of the work that I had proposed.

Yet, there are often moments of panic. The most worrisome thing I experienced was the realization – one that only a novice can have – that five years is a long time in the research area. In five years,

[4] https://www2.clarku.edu/offices/research/pdfs/NSFProposalWritingTips.pdf

complete fields disappear and new ones come up. As I was doing the work, new topics had emerged and older ones had become, well, old. I had to change or adjust my research to reflect these new realities. The other issue that came up and I now realize comes up with almost all projects is that most of the work doesn't go according to research plan that is laid out. For the most part, it's rare that I've been able to start the work exactly when I wanted either due to delays in funding or because of the timing of the funding that prevents hiring of personnel. People leave. Students graduate. Research study sites don't work out. Technology fails. And so on and so forth.

The other aspect that is worth keeping in mind is that even though the questions you proposed were well thought out and supported by the literature they just don't seem that good or relevant when you actually get into the field. This is more of an issue for qualitative research than experimental work. This is a predicament I've faced often and more often than not I follow my instinct in the field as I believe it is more likely to get me worthwhile and innovative data than blindly following what I had proposed. For instance, as I was doing field research in India I found a new site to study related to the use of technology for development and I followed that trail as ICT for development was becoming and has not becoming a core area of concern in development studies and also in engineering and social justice issues. There are also some issues that turn out to be too sensitive for informants to discuss, especially issues around ethics, and it was difficult for me to get data to answer those research questions.

This, once again, is the reason why a CAREER award funds the PI and their ability to do research as much as the idea. Research by nature is a dynamic enterprise and therefore it is essential to be able to change as the ground realities change. Does this mean you can do whatever you want? No. Within certain parameters you've flexibility to shift things around but you still have to contribute to the domain you intended to contribute to. With CAREER you should think of your contributions beyond just research articles and this means writing in more general audience publications but also your contribution back to the field and to your institution.

Finally, as with any qualitative study I ended up collecting way more data than I could analyze. I was trained to do research in a comprehensive manner where all data was collected and then analyzed thoroughly and over time I have come to believe this approach is good but not always practical. It is important to keep analyzing and writing smaller pieces throughout the research process. It was gratifying to hear a senior scholar, who has written over 20 books, say something similar at a faculty consortium once. If you wait too long you've too much to go through and new things come in the way. Analyze and write iteratively and build towards something bigger but always keep writing and sending stuff out.

In terms of advisory board, my interaction with them varied. With some of them I did regular updates and feedback session and with some things did not work out accordingly to plan often due to change in their career and life plans (retirements, change of institutions, travels, etc.).

Networking

The CAREER Award should allow you to make better connections in your field and network to make yourself visible in the research field. There are different ways to approach networking. A lot of people and researchers approach it in a very transactional manner where they do it because giving and getting is required in scholarship and if they do something for you, they expect something back. For a lot of people networking is more "socializing" – hanging out, having fun. Another way to think about it is in terms of building epistemic capital for your field – exchange of ideas. It's a personal choice how one approaches it and what one expects to give or receive but given that academic

communities are still largely volunteer organizations that function on free labor, participation is not optional. Reviewing is voluntary. Giving informal feedback to others is voluntary. Editorial work is voluntary. Organizing events is voluntary. Therefore, everyone has to pitch in. Networking is also critical to find new collaborators, to work with people with fresh ideas, to be able to rejoice in meeting people you enjoy working with, and to be able to spend time with people who have mentored you and those you've mentored.

If I Was Writing a Proposal to EEC Today

I think in the last decade the engineering education field has changed substantially in terms of the nature of research, the methodological depth, and the topics that are deemed relevant. I think theoretically and methodologically more depth will be required of proposals now than a decade ago. If I were to submit the same proposal the focus would be narrower, maybe two of the four questions I targeted. The theoretical framework will be more in depth and some aspects of the methods more spelled out. I would also be able to cite a lot more work directly in engineering education. Interestingly, at the time I submitted my proposal it was more theoretical and talked more about methods than the other two sample proposals prior EEC awardees had shared with me. I also believe that although I might now be competing with only 33% of the proposals the total pile, the overall number of proposals would be larger and the competition probably stiffer.

CAREER and Career

One of the major drawbacks of an academic career is that academics do a lot of invisible work and slowly we start believing the myth that the only form of work that matters is one that is immediately visible and rewarded – teaching, grants, and pubs. This often puts undue pressure on us because we start to forget that the rest also matters a lot; without the other tasks we take on, such as reviewing and mentoring, none of the visible work will get done. The conundrum we face is that not all of the invisible work we do matters to our institution or is rewarded by them and that is the thin line we have to walk – how much energy to put into things that seem to matter versus the rest of what we need to do?

There is also another aspect to the nature of our work and that is the ability and freedom to do what we actually want and like to do. Often as a new faculty this only seems like a luxury. The grind of doing work to get tenure and then often to become full professor makes us forget why a lot of us chose this profession. Our work starts to seem like that of a manager more than a scholar and this is especially true if you sit in an engineering school as opposed to in the social science or education. The nature of the job has indeed become that of one managing students, classes, committees and finding time to do the "real" work of scholarship is minimal. It is important to be aware of this. It is more important to make time to do the work that you enjoy. It can be a few hours each day, once a week, once a month, or even just in the summers, but you've to keep nurturing the aspect of your work that got you excited about this profession in the first place. And trust me, it's not easy. Life has its ways of intervening and if you don't consciously make time, you will not have it. Your career doesn't end with the CAREER. It's just the start.

The World is Against Me Syndrome

I want to end by addressing the issue of bias and favoritism in reviews and the award process. It exists. Having had many of my highly recommended proposals not get the money, I've no doubt that reasons beyond the merit of a proposal play a role in who, and what, gets funded. It still does not change how I go about writing your proposal. I'm not saying issues of bias and nepotism or favoritism should not be addressed, it's a shame that they exist, but always keep in mind the reality that still does not change is that your proposal should be of the highest quality it can be.

Also keep in mind that regardless of initial success or failure, proposal writing, especially in the early stages, is a lot about developing good habits. That should be your goal. An academic career really is a marathon and yes initial success determines tenure but even beyond that there is a lot of time left to do good work.

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CAREER: INVESTIGATING GLOBAL ENGINEERING WORK PRACTICES

The vision of my research program and the aim of this CAREER project are to transform engineering education by advancing fundamental knowledge of **how professional engineering practices have changed due to globalization and impacted engineers in the field.** This research will contribute to theoretical development in the area of global engineering education and provide an intellectual foundation to develop pedagogical resources to prepare globally competent engineers.

Motivation: The ability to work in a global world has emerged as the foremost skill that needs to be developed among engineers. Policy makers, academics, and practitioners all acknowledge that global collaboration is essential for sustained economic progress and for solving critical social and environmental problems. Over the past decade NSF, academia, and industry have invested significant resources to identify critical skills required by engineering students and practitioners to succeed in the 21st century. Informed by these findings an increasing number of research programs and institutions are devoting significant resources to prepare engineers for a global world.

Contribution: Although institutions continue to push this agenda forward, they are constrained in their efforts by the absence of comprehensive knowledge on global engineering work that can inform their pedagogical efforts. In particular, a systematic understanding of global work from the *viewpoint of practicing engineers on global teams* is absent. We know little about how globalization has changed what engineers *do* as they work on global teams – **who is this globally competent engineer we want our students to become?** My research fills a significant intellectual gap in engineering education by building a theoretical understanding of global engineering team work to inform *what* we teach and *how* we teach.

Research Questions: Preliminary studies by the PI – bolstered by scholarship in organizational science – establish that globalization affects *teamwork* in four significant ways (1) It increases team diversity; (2) It increases dependence on technology; (3) It creates unique challenges to on-the-job learning among team members; and, (4) It generates new questions about ethical conduct within teams. My study will explore each of these four factors in greater depth by asking **four specific** questions:

A. How does team diversity affect alignment of perspectives among global engineering team members?
B. How does technology pervasiveness affect work coordination in global engineering teams?
C. What informal learning practices do engineers develop and use in global engineering teams?
D. What personal ethical dilemmas do global engineers confront and manage in their teamwork?

Research Method: Research questions will be investigated through a **mixed-method qualitative field study**. Semi-structured interviews based on iterative protocol development will be conducted with 120 professional engineers at their place of work to develop an in-depth understanding and this will be followed by a survey of 250 participants to validate constructs and results developed from the interviews.

Integration of research and education will be concurrent and happen throughout the project by design and evaluation of **case studies** and **case preparation kits** on global engineering. Undergraduate and graduate courses on the topic will be offered and students will be engaged in research.

Project outcomes include: (1) Theoretical understanding of global engineering work, (2) Development of theory-based case studies, case preparation kits, and curriculum, and (3) Dissemination of case materials, curriculum, and research findings to the academic and practitioner communities.

Intellectual Merit: This novel project develops fundamental theoretical understanding of how engineering teamwork has been transformed by globalization and fills a critical gap in our efforts to educate engineers for the global knowledge economy. The proposed research is a true interdisciplinary undertaking and combines approaches from engineering education, organization science, technology studies, and learning sciences to bring empirical rigor to the topic. The PI is well qualified to undertake this research and has significant international work experience and field research experience with firms in the U.S., Germany, Ireland, Japan and India. To ensure project success clear addressable research questions, outcomes, and objectives have been identified; partnerships have been developed with industry and institutional stakeholders; and an advisory board has been set up to provide expertise.

Broader Impacts: This project will increase our understanding of diversity from an international perspective and have transformative impact on ~1000 undergraduate and ~50 engineering graduate students at Virginia Tech each year. A guide on working on global teams will be produced and disseminated to students, faculty, and study abroad offices of major universities in conjunction with Virginia Tech's Office of International Research, Education, and Development. An online repository of case studies and supporting curriculum will be developed and results will be published in academic journals and conferences and findings will be shared at workshops, special sessions, and through online platforms such as NSDL.org and GlobalHUB.org. Industrial partners and participants will also be provided with feedback and findings. Letters from different collaborators are included.

Comment [A1]: Concise overview of what this project is about and how it makes a contribution. I like using **highlights.**

Comment [A2]: So, this way of making different sections does not work anymore because the summary has to be entered as text but you can still play around to see how it looks and whether you can make it easy to read for the panelists.

Comment [A3]: 3-4 research questions are a good target for a CAREER proposal given the five year timeline.

Comment [A4]: Integration of teaching and research.

Comment [A5]: Why me? Make sure there is evidence in the proposal text to back this up.

Comment [A6]: Try to avoid being generic as much as possible and ground this in your institution so that you can have some impact.

CAREER: INVESTIGATING GLOBAL ENGINEERING WORK PRACTICES

PROJECT DESCRIPTION

1. MOTIVATION

"From the environment to medicine, transportation to communication, household appliances to space exploration, engineers affect the world. Yet just as the technology born of engineering has transformed much about our world, so has it transformed the work of engineers. Amidst complex challenges of unprecedented scale and urgency, the profession of engineering has new global significance—and responsibilities."

Educating Engineers: Designing for the Future of the Field (Summary), Sheppard et al. (2008, p3)

"*There is an urgent need for research on engineering in a global context*. The phenomenon of global engineering is still emerging. There is a need for a theoretical foundation on learning behaviors and models as well as on organizational processes and management methods focused on instilling global competence in engineers."

Global Engineering Excellence Initiative (GEEI) Report (Italics in original, 2006, p2)

"Understanding work and how it is changing is essential to all decision makers and advisors who educate and prepare people for the workplace, counsel them about career choices, assign them to jobs, and shape the organizational and institutional contexts in which people work."

The Changing Nature of Work, National Research Council Report (1999, p.1)

These quotes represent major voices from the engineering education community, the policy arena, and the industry, and capture three fundamental ideas: (a) engineers design their own lived world and the world of engineers has changed considerably due to technological advancement and globalization; (b) to better prepare future engineers for the global world we need to develop a thorough understanding of what global engineering entails; and, (c) this process needs to begin with an understanding of engineering work and professional practice. Together, they underscore the critical need to **build a comprehensive theoretical understanding of engineering work that can be leveraged to design effective pedagogical innovations to prepare globally competent engineers**. This objective forms the central guiding principle for this proposed research and the cornerstone of my overall research trajectory. In this proposed research **I will specifically examine how engineers work on global teams**.

1.1 Globalization and engineering education

Although globalization has been a political and economic concern for centuries (O'Leary, Orlikowski, & Yates, 2002) its impact on the engineering education community has become particularly salient since the publication of the "Engineer of 2020" (NAE, 2003) and "The World is Flat" (Friedman, 2005). These and subsequent publications (CSEPP, 2006; Duderstadt, 2008, EAP/IOE, 2008; GEEI, 2006; NAE, 2005) have emphasized the critical need to train globally competent engineers. Academics, practitioners, and policy makers alike have realized that solving the critical problems facing the world today and achieving the combined goal of the NAE Grand Challenges (NAE, Online) "better quality of life" will require close collaboration among engineers from around the world. Not surprisingly, educational institutions are investing millions of dollars to train students for success in the globalized economy through initiatives such as study abroad. Students, in turn, are spending significant amount of money to participate in these programs. The study abroad bill is another indication of the importance of this issue at the national level (Study Abroad Bill, 2009). From a research perspective, NSF itself spends upwards of 50 million dollars each year funding international programs (OISE, 2008). The greatest investment by far, however, has been by the industry. In 2007 alone U.S. firms spent over $134 Billion on workforce training (an average of $1,103/employee) (ASTD Report, 2007). Almost 21% of that amount was spent on training people to work with others and global issues are becoming a bigger slice of that pie with global work experience now considered a boost to industry careers (Infoworld, 2009). It is within this context that engineering educators are trying to make an impact to better prepare future engineers for the global world of work.

2. THE NEED FOR RESEARCH ON PROFESSIONAL ENGINEERS IN THE GLOBAL WORKPLACE

2.1 Overview of the current state of the field

Engineering education community and educators have developed a multi-pronged approach to educate globally competent engineers. To categorize different approaches adopted by educators and

Comment [A7]: This is more stylistic. I like this way to grounding the work through some quotes. Not always but sometimes. There are other ways to use this space so it's a matter of choice. I think it helps by not throwing something very "heavy" at the reviewers first up.

Comment [A8]: Why these quotes and how I am going to address the issues they raise.

Comment [A9]: Grounding in policy and larger debates around eng ed.

Comment [A10]: Practical implications of the work.

Once again this is a matter of choice whether to highlight theoretical or practical implications first.

researchers, I reviewed all studies related to global and international education published in the proceedings of the annual meeting of the American Society for Engineering Education (ASEE) (144 papers) and the Frontiers in Education Conference (66 papers) between the years 2003-2007. The proceedings were selected for their broad representation of the issues, at least from the U.S. academic and practitioner community, and for the short publication cycle that accurately reflects current concerns. The 5 year range was chosen as it coincided with the publication of Engineer of 2020 (2003) and The World is Flat (Friedman, 2005). A content analysis of the titles and abstract was carried out and all papers relevant to the proposal were read in full. Table 1 provides an overview of the major issues that emerged. **The noteworthy result from the perspective of this proposal is that workplace related studies represented only 5% of the total papers.** The findings further show that almost 40% of the papers describe or discuss some program or project that an institution, college or department has implemented to make their offerings more global. Almost 15% of the articles are about international activities such as study abroad, student exchange, or international research experiences, with study abroad the major component. Another 12% of the articles report virtual or online class offered between institutions in two different geographic locations. These classes aim to provide first-hand experience with virtual work giving students knowledge of issues such as effective use of technology, working across time zones, and forming common ground (McNair et al., 2008). Introduction of content about globalization within existing curricula or as new courses is discussed by 15% of the articles. One successful form taken by such curriculum efforts is to teach students about other cultures and cultural differences e.g. curriculum module developed by Downey and colleagues (2006), "Engineering Cultures," that teaches students the differences that exist among engineers from different nations, specifically their training and preparation. Finally, 20% of papers are a mix of issues such as accreditation or opinions of individuals.

Comment [A11]: To ground my work in the literature I did a thorough review of the field. This was easier to do in 2009 than it is now so you'll have to select some venues and make an argument for why those work best.

Comment [A12]: Punchline from the review.

Table 1: Distribution of ASEE and FIE papers over 2003-2007

Category	Number (Total = 210)	Percentage
Program Description (Institutional/Departmental/College Level)	80	38%
International Activities (Study Abroad, Exchange Programs)	30	15%
Virtual Class (Online Courses/Labs)	25	12%
Content Course (Full or Largely Global Component)	30	15%
Others (Accreditation, Opinion, Panel, Workshop)	40	20%
Workplace Related Studies (out of the total papers)	**10**	**5%**

Comment [A13]: This is not a very theoretical way of presenting the outcomes of a review but I believed it was needed before going in depth.

2.2 Intellectual gap in our current understanding: Lack of studies on work practices

From this analysis of publications and findings, a major intellectual gap is evident in our efforts to prepare an engineering workforce ready to work in a globalized world: **we have not yet examined engineering work practices or how engineers work with each other in firms**. This finding is echoed in the Global Engineering Education Initiative report (2006), "[T]here is a significant lack of knowledge about proven theories and effective practices for instilling global competence (p. 41)." Our current efforts are targeted towards understanding the preparation of engineers – their training and education – which has made us aware of their differences but not of their commonalities – common ground that can be harnessed for positive collaboration. Scholars have also started to express concern with study abroad for a lack of scale and argue that we need to look beyond study abroad programs (Miller, 2007) and provide experiences that can lead to a broader outlook among new engineers by aligning student training with the work of practitioners. There is a need to move form a simplistic list of attributes (e.g. ABET, 2008), and develop in-depth theoretical understanding of global engineering work that can be translated into teaching. The recent Carnegie report on "Educating Engineers" (Sheppard et al., 2008) and other scholars (Aldridge, 1994; Bucciarelli & Kuhn, 1997; Jonassen, Strobel & Lee, 2006; Lucena, 2006; Raju & Samkar, 1999) argue for a better fit between engineering practice and pedagogy.

Comment [A14]: Start to narrow down.

2.3 Contribution of the proposed study to the field: How engineers work on global teams

To address the gap between what a global engineer does and how we prepare students for that role a theoretical understanding of global engineering teamwork will be developed and translated into successful pedagogy through this proposed work. To achieve this goal I will start by examining and understanding the lived world of engineers who work in global firms as members of global teams. As the GEEI (2006) reports suggests, "increasing the knowledge base of proven theories and effective practices for instilling global competencies in engineering graduates…needs to be a major priority (p.42)." **This study will be the first major study into how engineers actually navigate the global workplace and**

work on global teams. The next and related step in combination with theoretical development will be the conversion of theories into pedagogical strategies and resources to educate students – this forms **the second major contribution of this work.** I will achieve this by connecting two bodies of knowledge – theoretical understanding of global engineering work practice and theories on how people learn (Jamieson & Lohmann, 2009; NRC, 2003). By integrating research and education – via case studies – this proposed work will provide an innovative model for translating theoretical findings into successful resources to prepare global engineers. **Figure 1** depicts the overall plan for this proposal.

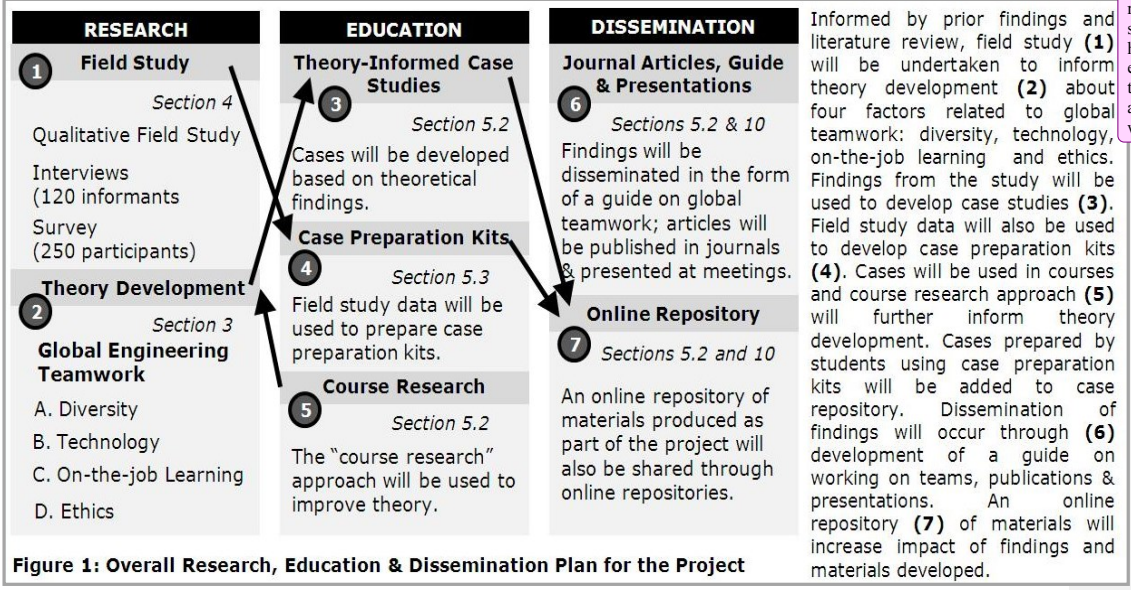

Figure 1: Overall Research, Education & Dissemination Plan for the Project

Comment [A15]: So, this took a long time to get "right". I'm a big fan of providing a guide map to reviewers of the whole proposal up front. I'm not sure it's always needed but at that time I thought it had value because it brought together research, education and dissemination – all the pieces together. This figure went through a lot of iterations and feedback on its usefulness was mixed from those who looked at the proposal before it was submitted.

3. THEORETICAL FRAMEWORK AND RESEARCH QUESTIONS

In a recent internal survey of IT staff at a large multinational firm (made available to me by the firm), all but 3 out of the total 256 respondents indicated that they worked as a member of a team. 40% of them worked in teams of 2-5 people and 35% in teams of 6-10. Furthermore, 24% of them worked with people across two time-zones and another 23% worked with people in three or more time-zones. They were dispersed across 10 nations in 15 different locations. Together they used a combination of 20 different kinds of technological devices or software to communicate; email, phone and remote desktop were the most popular. The survey also showed that most informants had no training in how to work on virtual or remote teams and/or on managing offshore projects. The respondents listed "knowledge transfer (41%)" and "team building (48%)" as the biggest challenges they faced. This survey is very telling of the realities of working in a global firm. It highlights the prevalence of teams, use of technology, and the diversity that comes from geographic dispersion, and the problem in learning and sharing knowledge. These characteristics reflect major findings of the NRC report on the Changing Nature of Work (1999) and recent literature on global work (Axtell, Fleck, & Turner, 2004; Gibbs & Gibson, 2006; Hinds & Bailey, 2003). Teams spread across locations, extensive use of technology, and diversity of workforce generate temporal, disciplinary, occupational, and organizational boundaries (Johri, 2008a). These boundaries in turn create severe interpersonal communication and coordination problems such as lack of mutual knowledge and common ground (Cramton, 2001), misattributions (Cramton, 2002), interpersonal conflict (Hinds & Mortensen, 2005), lack of trust (Jarvenpaa & Leidner, 1999), and difficulty in sharing knowledge and expertise (Majchrzak et al. 2000). **For workers on global teams, the world is not all that flat.**

Barley (1996) argues that work is one of the greatest concerns of everyday human life but one of the least investigated aspect and suggests that to build better theories of organization, we need to pay particular attention to how people work (Barley & Kunda, 2001). Motivated by documenting the effect of

Comment [A16]: Always good to make things concrete. Once again, this is an artifact of 2009 where the consensus was that the reviewers could be disciplinary engineering faculty and also industry members.

Comment [A17]: Counter factual statement to peek interest. At that time Friedman's "The World is Flat" was all the rage.

technology on how work gets done, workplace studies scholars have made work 'visible' by bringing to the forefront the tasks and actual practices of workers (Luff et al, 2000; Suchman, 2000). This stream of work suggests that only by looking at the actual practices of workers can we develop theory that takes the particulars of a profession into account. Therefore, investigating the **ways in which engineers do their work – work practices** – forms the foundation of this study. A few studies that have examined actual engineering work highlight the unique culture that develops among engineers (Bucciarelli, 1996; Kunda, 1992). In spite of the work in the organizational literature and increased calls to understand global engineering work, no study that I am aware of has examined global engineering teamwork from the perspective of practitioners. This proposed study fills this significant gap by exploring in greater depth three issues central to global teamwork identified above – diversity, technology, and on-the-job learning – and another central concern of engineering work and education: ethics. In addition to investigating these issues separately, I will uncover how these four factors interact as engineers navigate spaces of global work as team members. The domain of global teamwork is extensive and one essential objective of this proposed study is also to help define the area better in order to identify pathways for productive future research within the context of engineering practice.

Comment [A18]: Theoretical underpinning – practice-based studies. This also implies field studies.

3.1. Research Question A: How does team diversity affect alignment of perspectives among global engineering team members?

Comment [A19]: Research questions and how they are motivated. There were a lot of other things I could have looked at but according to the literature these were the most important issues.

The first factor affecting work on global teams is the increased diversity of team membership that creates boundaries not just of race, gender, and nationality, but also of disciplines, age, experience and tenure, educational background and other factors (Gibson & Gibbs, 2006). On global teams boundaries are often fuzzy (Mortensen & Hinds, 2002) making it hard to ascertain the membership of their teams and expertise of members (Johri, 2007a). This increases work uncertainty and leads to the development of faultlines among workers that result in subgroup formation (Fiol & O'Connor, 2005). Subgroups – an 'us' versus 'them' mentality – are historically affected by problems of trust and conflict (Cramton & Hinds, 2005). Within engineering, as Downey and colleagues have shown (Downey et al., 2006; Lucena et al. 2008; Pankhurst et al. 2008), differences arise among engineers as a result of the training that engineers go though in their home country. Engineers in different nations define problems differently and these differences create problems in understanding and need to be taken into account while working on global teams. But in the real world practitioners do move beyond an awareness of differences and bridge differences to work across boundaries. Bucciarelli (1984, p. 187) even argues that this is one of the main roles of design, "The task of design is then as much a matter of getting different people to share a common perspective…as it is a matter of concept formation, evaluation of alternatives, costing and sizing – all the things we teach." What this suggests is that working on a team requires alignment of diverse perspectives held by team members on the problem, solution, task, roles and so on and this goal is harder to achieve in global teams due to greater diversity. In a recent study I found preliminary evidence that global team members were able to align their perspectives under certain conditions and complete their task successfully (Johri, 2009 b,c). By following this line of work further and studying the different mechanisms that allow global engineering team members to align diverse perspectives, we can build theoretical understanding that can be used as a basis to design case studies that can impart these kills to students. In future work, the answer to this question can also help develop technology-based learning environments (e.g. Ellis et al. 2008) where students can be trained to work successfully on global teams.

3.2 Research Question B: How does technology pervasiveness affect work coordination in global engineering teams?

Comment [A20]: There is motivation through literature and then personal interest. Technology was something that I always wanted to look at.

The second aspect of globalization that has affected engineering work is the exponential increase in the use of information technology (Fulk & Collins-Jarvis 2001; Hinds & Kiesler, 2002). This dynamics was well explored by Friedman (2005) from an international perspective but is equally applicable at the level of actual work coordination (Cummings, 2004; Malone & Crowston, 1994). Technology creates immense opportunities for collaboration across time and space but, as discussed earlier, it also generates boundaries that inhibit interpersonal interaction (Gibson & Gibbs, 2006; Hinds & Bailey, 2003). Since distributed workers are usually unable to share direct experiential knowledge they must rely on interactional dynamics and category membership that are mediated by technology. Communication in these mediated environments is a "leaky process" (Cramton, 2001, p. 364) and can contribute to bias, partial information, lack of trust, misunderstandings, and conflict, especially between people who lack mutual knowledge (p. 349). The consequences of failure to establish mutual knowledge are harsh and

include poor decision quality and productivity and less effective conflict resolution. They require constant maintenance of awareness (Weisband, 2002). These problems are particularly salient in coordinating work across locations. Coordination is critical for engineering work – especially large engineering projects – as different elements of a project that are being worked on at different places need to be aligned for the final product. Dispersion across location increases the need for and complexity of coordination among different team members. Engineers in a single location share common norms, have easier access to expertise, and the ability to engage in informal spontaneous communication (see review in Kiesler & Cummings, 2002). Distance reduces collaborative opportunities and effectiveness (Galeghar, Kraut & Egido, 1990). The interaction of distance with technology increases the complexity of work and affects professional engineering work (Crowston & Howison, 2004; Espinosa et al., 2001) since digitization of engineering work has resulted in the use of systems that affect coordination directly. For instance, in software development coordination is achieved not just through increased use of communication channels, but the use of the software code itself as a coordinating mechanism (Aneesh, 2006; Metiu, 2006). Recent studies suggest that technical artifacts often play the role of boundary objects – helping different stakeholders find common ground and bridge perspectives (Boland et al., 2007; Carlile, 2002; Kellogg et al. 2006). As yet, we do not have in-depth understanding of work coordination through technology from the perspective of practicing engineers and this research questions will help us establish the connections better.

3.3 Research Question C: What informal learning practices do engineers develop and use in global engineering teams?

On-the-job learning forms the third dimension of global engineering work that I will investigate. According to Katehi (p.152-153), to become global engineers U.S. engineers, "will have to know how to replenish their knowledge by self-motivated, self-initiated learning…The engineer of 2020 and beyond will need skills to be globally competitive over the length of her or his career." Although learning can be categorized along many dimensions, formal and informal learning are two key dimensions that appear in the literature (NRC, 2003). Formal learning involves environments that are designed and institutionalized – classrooms and courses for instance. Informal learning, which is a more common form of learning over the lifetime, involves interactions and knowledge building that occurs as people engage in activity in the course of daily life or work (Greeno, 2006). For instance, research shows that a miniscule part of our lives is actually spent in formal learning environments and that this time greatly reduces over time, from a maximum of 18.5% during K-12 to 1-2% after graduate school (Pea, 2007). The workplace has been a site of investigation for research on learning for decades and scholars have characterized its nature as cognitive apprenticeship (Collins, 2006; Lave & Wenger, 1990). Furthermore, on-the-job learning is strongly dependent on informal interaction among workers (Orr, 1996). For engineers, and others in technical professions, learning involves acquiring both social and disciplinary knowledge that can allow workers to participate in a community of practice (Johri, 2007b; Wenger, 1995). Within the context of global work the ability to draw on expertise and knowledge of workers is one of the primary advantages of working with people around the world. Studies show that global teams do produce better output and are more innovative as a result of their diversity and the diverse knowledge that team members bring to the table (Cummings, 2004). Yet, this process is problematic due to difficulties in communication and coordination – as discussed previously – and also due to the situated nature of knowledge in the workplace (Brown & Duguid, 1991; Elsbach et al. 2005). Learning occurs in specific context and 'what people learn' and 'how they learn' are both embedded in particular space and time and this makes on-the-job informal learning across locations – without shared context and practices – hard to accomplish (Sole & Edmondson, 2002). For instance, in a recent study, I found that newcomers often had a preference for face-to-face interaction during their initial time in the firm and then found it easier to work virtually as they were better able to learn on the job (Johri, 2009d). Yet, the same newcomers also reported successfully working on Open Source projects without ever meeting other team members face-to-face. This suggests that one aspect of learning – learning about organizational context – might require being physically embedded in the work context and when that context is digital (such as in "Open Source"), negligible amount of physical interaction might be sufficient (Johri, 2009d). This preliminary work suggests that on-the-job learning in global engineering teams is critical for the success of teams and of team members. It also suggests that it is a complex process the requires further in-depth investigation to go beyond identification of skills and build a detailed understanding of what is learned and how it is learned in order to leverage the findings to design pedagogy for training future engineers.

3.4 Research Question D: What personal ethical dilemmas do global engineers confront and manage in their teamwork?

Finally, an important aspect of global work that has not received much consideration from the perspective of engineers on global teams is ethics. Colby & Sullivan (2008) emphasize that, "Although the formal engineering codes of ethics do not generally spell out the complexities that globalization of engineering work has added to these issues, every one of these keys topics delineated by the ethics code is affected by the pervasive and growing influence of globalization (p. 328)." Within the context of engineering education, ethical issues are increasingly becoming part of the curriculum (ABET, 2008) but the coverage is still limited in both quantity and quality (Colby & Sullivan, 2008; p.332-333). In particular, Colby & Sullivan (2008) found that, "though teamwork was used extensively in these programs, faculty seldom highlighted they key dimensions of professionalism entailed in successful teamwork, including a sense of personal responsibility, fairness and honesty within the group, and a climate of respect and trust (p. 333)." In global teams, members have to take decisions on a day-to-day basis that are not clear cut and require them to make ethical trade-offs. Standards of practices often differ across locations and issues such as honesty, fairness, power, and status are more convoluted than in co-located teams. For instance, I found that workers blamed coworkers in locations with more resources – usually Western countries – of not doing enough work whereas workers in resource intensive locations argued that coworkers in other locations have it easy as they are not under scrutiny all the time (Johri, 2007a). I also found that team members in non-headquarter locations – usually Asia – made significant adjustments to their lifestyle to accommodate teleconference meetings with coworkers in the central locations – staying up till 1 or 2 AM or waking up at 5 or 6 AM. It was clear to them, and to their coworkers, that they were not on equal footing creating an ethical interpersonal dilemma. These preliminary observations establish that ethics is a critical issue in global engineering teamwork and needs to be investigated further in order to develop better theoretical understanding and a body of work that can be used for teaching.

Comment [A21]: Interestingly these are still the issues I'm examining a decade later.

3.5 Integration of Findings from Research Questions A, B, C & D

As is evident from the literature review in the above sections, the boundaries around the four factors – diversity, technology, on-the-job informal learning, and ethics – are analytical boundaries. In practice, on-the-job learning makes extensive use of technology and diversity of team members increases the probability of different viewpoints and perspectives, leading to increase learning among team members. Ethics are closely tied to diversity – whose perspectives are more valuable – and even technology – who gets access to critical resources required to accomplish work. These different relationships will be further teased out in the findings to build a comprehensive understanding of working on global teams from the viewpoint of practitioners.

3.6 Career Development Plan and Relationship of this Study to PI's Research Trajectory

Within the next 5 year span my research plans are aligned significantly with the work proposed here. I am interested in building a comprehensive body of work on global engineering teamwork starting with the four core issues identified in the research questions. Together with my prior work (see section 7.1) and work currently under review and publication, this research will lead to a foundation that I hope to continue along a few different lines. The work proposed in this CAREER proposal will also form the backbone of integrated research into the future of engineering profession and engineering learning. Following this work, in the 10 year horizon I will pursue this work to examine the emergence and increased use of teleworking by engineers and issues of work-life balance (Perlow, 1997). Learning beyond formal schooling and lifelong learning is another key area that I will develop further and examine comprehensively in the context of engineering work. From an efficiency based model (Callahan, 1962), we need to shift education to a participative and personalized experience (NSF, 2006) using technology and my research on the use of technology will directly contribute to this goal. Further, I will address changes in engineering work practices due to mobile devices. The mobile workforce is predicted to be over 1 billion workers by the year 2011, with nearly 75% of the US workforce mobile (IDC Report, 2007). I envision the future of engineering work to be more inclusive and egalitarian and the workforce more diverse through the emergence of platforms that allow large number of users to productively participate in design and decision making (e.g. Wikipedia). This has huge implications for engineering and constitutes another area I will pursue – who gets to participates across the globe, how, with what ethical implications.

Comment [A22]: Very CAREER proposal specific section. People have different feelings about how important it is.

Interestingly my research trajectory has stayed quite close to what is outlined here.

4. RESEARCH METHODS, PROPOSED DATA COLLECTION, AND DATA ANALYSIS

4.1 Study Design: Qualitative Field Study Incorporating Mixed-Method Data Collection

The problems of global engineering teamwork and preparing students for the global world are closely interlinked and can only be addressed through a grounded and in-depth understanding of the world of practicing engineers. This requirement leads naturally to a qualitative file study as qualitative studies are well suited for research that aims to describe a phenomenon and look at a process in naturalistic settings leading to theory-building (Creswell, 2003; Marshal & Rossman, 1999). Elsbach (2005) has identified three specific advantages of qualitative studies for theory building pertinent to this proposed study: (a) qualitative data allow a rich theory to develop as the complexity of data "gives a picture of informants' meaning of the social world and behavioral processes that might not otherwise be available (p.10)." This rich data is crucial to provide explanations; (b) qualitative data allow a researcher to "capture the dynamics and evolution of social processes over time (p.11)." This is particularly true of participant observation and certain interviewing strategies that allow researcher to build an understanding of attitudes and behaviors as they change over time; finally, (c) qualitative data allow us to link data to the experiences of informants, experiences that are meaningful to them, which allows for theory building that can explain natural behavior. The questions I address in this study require qualitative data in order to lead to meaningful theory. Questions A & B require an examination of process and an understanding of informant's interpretations to develop a theoretical understanding of mechanisms that 1) affect alignment of perspective among engineers on global teams and 2) affect work coordination among engineers as they depend increasingly on technology. Questions C & D require in-depth contextual understanding of the dynamics of on-the-job informal learning and the attitudes and behaviors of engineers on global teams regarding ethical issues faced by them. Overall, the ability of qualitative data to allow theory-building that is rich, process-oriented, and contextual is an immense benefit to researchers attempting to explain and learn from human behavior in particular contexts. This approach is also supported by Johns (2006) who argues that to understand how organization and behavior are interrelated one needs to undertake a contextual study by collecting qualitative data as it is sensitive to full range of contextual factors as well as full range of behaviors. Therefore, data collection and analysis have been designed to ensure they result in a rich set of data that is contextually situated.

The primary unit of analysis for this study is the individual therefore data will be collected from individual informants working on global teams. This strategy has the benefit of allowing theory building to occur by taking into account responses from engineers in a variety of settings that perform a diversity of tasks. This cross-case comparison at a large scale is essential for theory building (Eisenhardt, 1989) as it permits enumeration and allows the researcher to discern variability across contexts. Working at the individual level will also make it easier to add more data points if needed. Whenever possible, more than one individual from a team will be interviewed to get different perspectives especially if the informants are in different locations. With the assistance of a graduate student, I will also collect concurrent data at different locations a team distributed across those locations.

4.2 Data Collection

Interviews will be done during first three years of the 5 year effort. Each year 40 informants will be interviewed and related participant observation data collected. A total of 90 informants will be members of global teams and 30 informants will members of traditional teams and form a comparative sample. Interview protocol will be refined before the next stage based on analysis of data collected in the previous year. Survey will be administered to 250 participants (200 global team members; 50 traditional team members) in the fourth year. The survey will be available online and data collection will be open for three months. Participants will be invited and assigned a unique identifier to access the survey (to protect anonymity). International data collection is a significant component of this research study and extensive planning will be done to ensure the collection of necessary and sufficient data (quantity and quality). I have considerable experience with international field studies (see section 7.1 for details) including IRB permissions. Data will be collected using a mixed-method approach where interviews, supported by observations, will yield the core descriptive data and surveys will be used to assess the generalizability of constructs.

4.2.1 Interviews: The primary data collection will occur through semi-structured interviews designed to address the four research questions of the study. The interview protocol will consist broadly of four sections corresponding to each research question. Not every informant will necessarily be able to talk

Comment [A23]: I was trained in qualitative research and that is what I wanted to use in the research project but those who gave me feedback made a strong argument for including some form of survey data to make it "comfortable" for reviewers from the quant paradigm and also to make it easier to get access to field sites. Companies are more used to concise feedback and surveys help with that.

Comment [A24]: This is not something we pay enough attention to but it is important.

Comment [A25]: It is hard to figure out the right numbers but based on my prior experience I thought this was a good number and also doable.

After the proposal was recommended the budget was reduced and correspondingly these numbers were reduced as well.

At the end, data collection was not the issue but as is often the case data analysis was. There is always too much data.

about every issue and therefore the focus for each interview might differ based on the informant. This is quite common in interviewed based studies and the large sample size (120 informants) will ensure that each issue is sufficiently represented in the overall data. In addition, often the non-emergence of an issue during an interview is itself an interesting piece of data and can be explored in-depth later. The protocol will be refined using iterative design methods and saturation sampling will be used to stop asking certain questions. Interview structure will be developed based on Spradley's Ethnographic Interview (1979) to make sure to take into account the context of interviewees and the protocol will be further refined to include strategies suggested by Merton (1990), McCracken's (1988) and Seidman (1998). Kvale's (Kvale & Brinkmann, 2008) story elicitation and use of artifacts or artifacts-based interviews will form a key component of the data collection methodology. My approach to research and field study in particular can be categorized as "ethnographically informed." This approach involves trying to understand the world of an informant from the informant's perspective. It helps uncover interpretations that inform decisions made by workers (Daft & Weick, 1984). To achieve this, interviews will be contextually embedded – they will occur in the interviewees' work context. I consider **participant observation** integral to any interview-based field study such as the one proposed here. My prior work has involved extensive observational study (see Section 7.1) and I have developed different sets of protocols that help me uncover interesting and suitable data to help triangulate findings (based on Lofland & Lofland, 1994). I have used the "shadowing" method successfully and will employ it in this study as well. In this method selective informants are followed closely as they go about their work, providing an intimate view of their practices.

4.2.2 Surveys: In addition to interviews, surveys will be used to assess the validity and generalizability of findings from interview data. Two kinds of surveys will be used, social network surveys to identify who works with whom, the nature of their interaction, and the results of their interaction. Secondly, surveys will be designed to directly validate mechanisms and constructs derived the interviews. These surveys will be based on PI's prior work (Johri, 2007a) and work of Herbsleb et al. (2000) and Cummings (2004). Both researchers have shared their highly cited and assessed surveys on global teams with the PI. Survey items will be tested on a smaller sample before being deployed in the field. Online survey instruments will be used (Virginia Tech has a proprietary service and also subscribes to SNAP). **Statistical measures** used will include social network analysis measures (centrality, closeness, etc.), simple descriptive statistics, measures to calculate the strength of mechanisms, and different measures of dispersion (see O'Leary & Cummings, 2007).

4.2.3 Archival Materials: Archival data will form a core component of this study. Any organizational study and organizational settings provide extensive opportunity for unobtrusive data collection (Webb, Campbell, Schwartz & Sechrest, 1966) and the prevalence of technology in global teamwork further facilitates such data collection through archival electronic data. In my prior research studies these materials have included emails, minutes of meetings, online transcripts of chats, publications, technical reports, monthly activity logs, memos, PowerPoint presentations, audio files, video files, Flash files, and content on the Intranet (Johri, 2005, 2007a). The organizational Intranet is another rich resource of data such as calendars and work schedules. Archival materials are a significant resource for data triangulation often providing a relatively objective support to an event or incident referred to by an informant and can be used as mnemonics to assist the informant in recollecting an event or episode.

4.3 Data Analysis

An iterative data analysis process will be followed based on Strauss's conception of grounded theory analysis that provides guidelines on how to analyze qualitative data collected through literature and prior work driven research questions (Strauss, 1987; Strauss & Corbin, 1998). When there is already a sense of what one is looking for the method Strauss (and Strauss & Corbin) advocate is more appropriate as opposed to basic grounded theory (Glaser) that presupposes no familiarity with the data or themes and relies solely on emergence of ideas from the data. Interview protocols will serve as initial templates for analysis. Through previous studies I have developed an analysis technique based on events that includes triangulation at its core and consists of the following steps (Johri, 2007a; 2009b). First, all interviews and field notes will be read "microscopicly" and open coded for data pertinent to the research questions. This will be followed by axial coding and data memos will be prepared around events and lead constructs derived through data triangulation. Throughout the analysis, emerging trends will be identified and noted and any event or activity that is salient will be used a marker to elicit additional response from informant in the next data collection cycle. The iterative analysis cycle will involve looking at the literature during the process as well to help with constructs (using Becker's (1998) notion of "Concept") and three cycles of

Comment [A26]: I was very comfortable with writing this section as I was well trained in methods. There are a million ways to do interview and observations and how I do it reflects my training. When it comes to data collection you've to propose to do and do what works for you. It has to be systematic and comprehensive (and reliable and valid, etc.) but over time we all develop our own way of doing research. The thing to remember is that if you don't create a good way to do it, it will hurt you in the long run. Replicability is good not just for the field but also for your own sanity.

Comment [A27]: Both these senior scholars were generous enough to share their survey instruments with me.

Comment [A28]: Often overlooked but this is a method for data collection that has led to some of my most interesting findings. It can be time consuming.

interview-based data collection and a final cycle of survey data collection will occur will allow both the development of useful constructs and their testing through the surveys. The software NVivo will be used for qualitative data, Excel and SPSS for quantitative data, and NetVis for social network data analysis.

Table 2: Overview of Research Approach and Methodology

Research Question	Methods and Analysis	Data Collection &Sample
A. How does team diversity affect alignment of perspectives among global engineering team members?	*Interviews protocol* to collect data about specific events and breakdowns while working on global teams. *Surveys* to assess mechanisms derived from the interview data. *Analysis* will involve in-depth examination of interview data which will be validated through the survey.	*Year 1-3*: Interviews with a sample of 120 informants *Year 4*: Survey with a sample of 250 participants *Year 5*: Follow-up if needed
B. How does technology pervasiveness affect work coordination in global engineering teams?	*Interview protocol* to ask about technologies need for coordination, mechanisms for coordination. *Surveys* to provide data on dependencies and need for coordination. *Analysis* will include in-depth examination of interview data to identify mechanisms which will then be validated with a larger sample using the survey.	*Year 1-3*: Interviews with a sample of 120 informants *Year 4*: Survey with a sample of 250 participants *Year 5*: Follow-up if needed
C. What informal learning practices do engineers develop and use in global engineering teams?	*Interview protocol* will ask for situations that involved learning as well as give scenarios that need learning and how the informants will proceed. Taxonomy of learning activities and skills that informants develop will be validated through *survey* data. *Analysis* will involve grounded investigation of interview data and quantitative analysis of survey data.	*Year 1-3*: Interviews with a sample of 120 informants *Year 4*: Survey with a sample of 250 participants *Year 5*: Follow-up if needed
D. What personal ethical dilemmas do global engineers confront and manage in their teamwork?	*Interview protocol* will ask them for their view on ethics, ethical issues they think they have faced and how to they confronted them. Taxonomy of ethical behaviors and concerns mentioned by informants will be developed and validated through the *survey* with a large sample size. In-depth and quantitative *analysis*.	*Year 1-3*: Interviews with a sample of 120 informants *Year 4*: Survey with a sample of 250 participants *Year 5*: Follow-up if needed

Comment [A29]: Once again, a concise way to provide an overview of what you are actually going to do and when.

4.4 Sample and Recruitment of Participants

The total sample size for interviews is 120 informants and additional 250 participants will be recruited for the survey. Participants for the study will be recruited through several sources. As the research design calls for data collection at the individual level the focus is not on recruiting whole teams or organizations but engineers from a diverse range of settings. Purposive snowball sampling (Miles & Huberman, 1994; p. 28) will be employed through already existing contacts of the PI developed through previous studies (for instance, see letter from XYZ), through professional networks and sites such as LinkedIn, and through alumni networks to which the PI has direct access. Informants working on global teams in engineering firms will be asked to introduce the PI to other engineers in similar roles. Several other firms have been approached and have expressed an interest in participating such as A, B, C, & D. In addition, the Dean's office at Virginia Tech has agreed to collaborate with the PI in this effort and they already have an existing database and network of alumni engaged in global work (see letter from ABC). XYZ a member of the advisory board, has also agreed to aid in this process through his extensive network and working partnerships (see letter). To get a comparative sample individuals working in traditional teams will also be included in the sample (30 informants). These participants will come primarily from PQR (see letter). The sample will be stratified to include engineers on diverse projects, with different disciplinary training, and from different nations. As mentioned previously, data collection will be international in scope and travel is an essential part of the process. When possible, travel will be used to collect data from dyads – informants at different locations who work with each other – to better triangulate the data and the findings. Finally, I want to restate that I am well versed in the proposed methods and they constitute an area of expertise for me (please see sections 7.1 and 7.2).

Comment [A30]: Very important for the work I was proposing as I needed access to professional engineers to make it all work. I was lucky to get at least one company lined up (I've removed the name for privacy).

5. INTEGRATION OF RESEARCH AND EDUCATION: CASE-BASED APPROACH

The integration of research and education is at the heart of this project and will occur concurrently throughout the project. **Figure 1 represents the plan for each year of the project.**

5.1 Theoretical Contribution and Practitioner Guides (Steps 1-2-5-8)

Theory development is central to this project and data from field study will result in publications and presentations. Findings will also be distilled in the form of guidelines for practitioners and educationists. But beyond these outputs, **the novelty of my approach lies in the use field study data to integrate research and education through a case-based approach**.

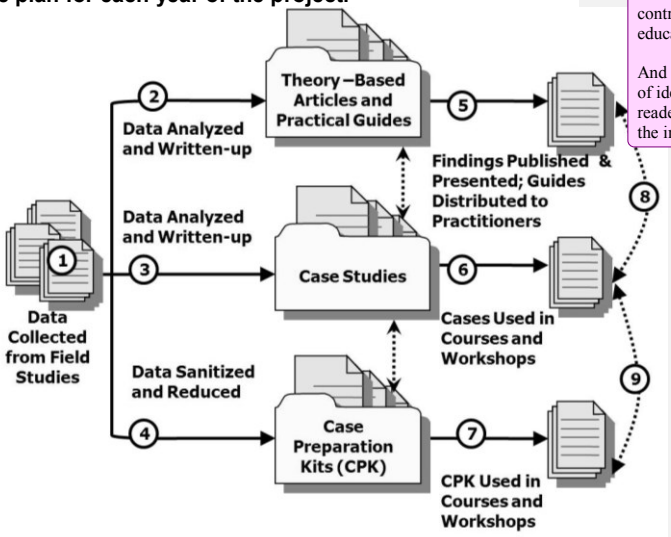

Figure 2: Steps in Integration of Research and Education

5.2 Theory-Informed Case Studies (Steps 1-3-6-8)

First, the data will be used to build theory-informed case studies (Step 1-3). Cases, which consist of narratives or scenarios abstracted form real world situations, have been used as learning resource in diverse disciplines for many years. Approaches such as case-based reasoning (CBR) and problem-based learning (PBL), are just a couple of examples of the use of cases (Kolodner et al., 2003). Cases have also been used as part of adaptive expertise based curricula in engineering education (Martin et al. 2007, 2005). Aldridge (1994) made a call to engineering educators to adopt a case based approach to teaching with cases derived from actual engineering practices and Raju & Sankar (1999) have also advocated the use of case studies to teach real-world issues to engineers. What makes cases, and case studies, attractive for teaching about global work strategies is their success in the business domain, especially to teach organizational behavior and institutional issues. These case studies perform a critical function in learning – they go beyond abstract formalism and provide a situated and grounded understanding of a concept to students. They encourage peer learning and in particular dialogic learning among students (Johri, 2009e). Moreover, from a researcher, the discussion of cases in class leads to generation of ideas and knowledge building (Scardamalia & Bereter, 2006), and issues that can be further investigated in the field. Finally, cases allow the discussion of core issues informed by theories of how people work together.

Not surprisingly, case studies of global work that address issues faced by engineers are in short supply. For instance, currently I use case studies produced by management scholars that discuss issues pertinent to global work but address issues primarily from an organizational or strategy perspective. Each year new cases will be generated and tested in class and in the next cycle newer cases will be developed (Step 6). Overall, 12 case studies will be produced from the research project. In addition to online dissemination planned for pedagogical materials resulting from this work (see section 10) **I have also been invited by EFG (see letter) to submit a book proposal to publish the case studies as part of the series XYZ.** To build theory through the use of cases in class, the "course research" theory building approach of Christensen and Carlile (2009) will be adopted. This approach built over decades of use of cases in courses argues that theory building occurs in two stages "descriptive theory" and "prescriptive theory" and that using cases in courses helps researcher refine their theory and by engaging students productively it leads to better theories and learning in class (Step 8), which in turn will shape the writing of new cases. Class discussions and student feedback, often based on their own experiences, can lead to both inductive and deductive theory development and improvement. This "course research" approach makes teaching integral to research and vice versa. In addition to courses, cases will be used in workshops for study abroad students and at conferences.

5.3 Case Preparation Kits (Steps 1-4-7-9)

Comment [A31]: Another figure that took a long time but one I wanted as it captures the project contribution and integration of research and education.

And yes, there is repetition throughout the proposal of ideas but I think it is important to remind the reader of what you are actually going to do and what the implications are of your work.

Comment [A32]: I had done prior work to test out ideas to make sure they work.

In addition to case studies, a novel approach will be deployed to integrate teaching and research – *case preparation kits (Step 1-4)*. This is an innovative pedagogical tool that I have developed to teach students situated decision making about global engineering work. This approach is founded on the "teaching to learn" paradigm and recent findings in the learning sciences on teaching about complex systems (Goldstone & Wilensky, 2008; NRC, 2003). Global engineering work is an inherently complex task and as Goldstone and Wilensky (2008) argue, teaching about complexity requires, "students to actively interpret the elements and interactions of perceptually grounded scenarios." Therefore, in this approach I give students masked data from actual field studies that I undertake and ask them interpret it and develop a case study that can be used to teach other students about any particular aspect of global engineering work (Step 7). To be able to develop a resource that can be used to teach, the teacher has to build a conceptual understanding and then devise ways to first give information to students and then engage them in ways to build knowledge (NRC, 2003), a critical competency for the Engineer of 2020 (NAE 2005). Working on case building also exposes the students to paradoxes inherent in any complex situation and ways in which informants work through these paradoxes. Furthermore, cases produced by students will add to the body of cases that can be used for teaching (Step 9). Since the cases will be linked to theory, working on cases will also iteratively lead to theory generation and recognition of gap in the literature if the body of knowledge does not exist to teach some issues. A similar approach has been adopted by Lambert (2009) at Waterloo with success where they give students data about a house and ask them to prepare cases on making the house more sustainable. A modular approach will allow users to integrate cases and case preparation assignments without needing to build completely new curriculum or course and by using specific material they find useful in conjunction with already existing courses.

5.4 Assessment of Integration of Research and Education

The overall use of case studies and case preparation kits relies on the curriculum structure within which they are used and I assessed their value in a special study course I offered in Spring' 09 on "Global Engineering Work Practices (see Section 7.2)." The course consisted of readings that cover the historical background of global trade and global work, current drivers and issues of global work, and theoretical readings on how people work with others. For instance, to teach students about bridging perspective by building mutual knowledge and common ground, readings on that topic were assigned (references [9]-[10]). A case study on the topic was discussed and analyzed and then data from one of the field studies was given to students to develop a case (the students undergo IRB training and certification and the data were masked to protect the identity of informants and details of field site). I provided them guidance during the assignment and feedback on their draft. Finally, a class project where students worked virtually with other students was used to simulate the need to develop common ground, create a common identity and construct work practices. The effectiveness of the approach was measured through an assessment instrument and the overall feedback from students was extremely positive and learning gains were achieved (Johri 2009a; 2009b). ***Preliminary assessment*** of the course showed not only high student satisfaction (3.75/4.00) but also learning on key concepts (75% on a concept evaluation). In their feedback on course improvement students asked for more course content and case studies related to engineers and this weakness will be directly addressed by this study.

In addition to assessment instruments I have developed, ***future assessment*** of integration of research and education will incorporate the rubric developed by Shuman et al. (2004 & 2005) to assess students' ability to recognize and resolve complex, open-ended ethical dilemmas. Students' written responses to case studies will be coded for five components: recognition of dilemma (capacity to identify and frame key dilemmas), information (recognition and appropriate use of pertinent facts), analysis (such as citation of analogous cases), perspectives (consideration of multiple points of view), and resolution (consideration of risks, development of creative win-win solutions). The test-bed to assess the case studies will be by my courses (see section 7.2) and students participating in study abroad (see letter). Pre-existing assessment instruments from resources such as the Online Evaluation Resource Library (OERL) (http://oerl.sri.com/home.html), Field-Tested Learning Assessment Guide (FLAG) (http://www.flaguide.org/), and Student Assessment of Learning Gains (SALG) (http://www.salgsite.org/) will be modified and adopted in accordance with the "Knowing What Students Know" publication (NRC, 2001). The formative and summative assessments for the CAREER project will be done with assistance from advisory board member ABC (see letter), an expert on assessment of international projects.

Comment [A33]: Another required and important section for the CAREER proposal.

Comment [A34]: Prior work in teaching

Comment [A35]: Important to demonstrate that you've done your research and are not going to reinvent the wheel when it comes to dissemination.

6. TIMELINE AND DETAILED PLAN OF PROPOSED ACTIVITY

Table 1 shows the proposed time line of the project. I will follow an iterative process that will include data collection, analysis, writing, and development and testing of cases each year. Theory-building will occur each year and this will provide the opportunity to modify the data collection for the subsequent year if needed. In years 1-3 the data collection will primarily be interview-based whereas in year 4 survey data collection will be the primary method. Year 5 will focus more on analysis and dissemination.

Table 3: Timeline and Plan of Proposed Activity

Fall2009	Prior work and planning for the project (including IRB approval)	
	TIME PERIOD	**PROPOSED ACTIVITY**
YEAR 1 (2010)	Spring 2010	Preparation and planning for the field study, interview guides and schedules
	Summer 2010	Data collection in the field; Total: 40 interviews over 2 months; Transcription
	Fall 2010	Coding & initial analysis; Case and Case Preparation Kits (CPK) developed; Preliminary results submitted for publication
YEAR 2 (2011)	Spring 2011	In-depth Analysis, Refinement & Writing
	Summer 2011	Data collection in the field; Total: 40 interviews over 2 months; Transcription
	Fall 2011	Coding & analysis; Case and CPK developed; Results submitted for publication
YEAR 3 (2012)	Spring 2012	In-depth Analysis, Refinement & Writing
	Summer 2012	Data collection in the field; Total: 40 interviews over 2 months; Transcription
	Fall 2012	Coding & analysis; Case and CPK developed; Results submitted for publication
YEAR 4 (2013)	Spring 2013	In-depth Analysis, Refinement & Writing
	Summer 2013	Start preparation of case studies; Survey data collection (250)
	Fall 2013	Survey data follow-up; Case and teaching refined and tested in courses (Evaluation Cycle 1); Results submitted for publication
YEAR 5 (2014)	Spring 2014	Survey data analysis; Testing of case and teaching material (Evaluation Cycle 2); Survey follow-up if required
	Summer 2014	Write-up of survey results; Preparation of final report, guide book for educators and practitioners
	Fall 2014	Final revisions of cases and teaching material and guidelines Dissemination: Workshops, publications, online repository
Year 6++	Dissemination of findings; future research that builds on findings from this work.	

Comment [A36]: Good to show this in a single table. It should seem doable in addition to being comprehensive.

7. PRIOR WORK RELEVANT TO THE PROPOSED RESEARCH PLAN

7.1 Prior Work Experience and International Research Experience: My experiences and interest in international work began during my junior year in college when I interned with Honda Motors in India. In my internship I was fascinated by the dynamic between expatriates from Japan and local employees from India and the acceptance by Indian workers of the Japanese emphasis on quality, something entirely foreign to most local Indian firms. My first job after finishing undergraduate studies landed me in Bangalore, India, on a project for GE with team members in the U.S., France, Japan, and India. This work experience further piqued my interest in global work dynamics and motivated me to study social dimensions of engineering practice and led to degrees in communication, technology design, and learning. Subsequently, this topic has become the primary focus of my research and since then I have engaged in field research with firms such as X, Y, Z and I have undertaken research in the U.S., Ireland, Germany, India, and Japan. I have conducted over 200 interviews, 5-6 months of participant observations, and numerous surveys. The findings from these studies have been published and presented at several venues. I have also been involved with other international projects such as the use of handheld devices to improve efficiency of vaccination in developing countries, a project that won the first prize at Social Entrepreneurship competition at Stanford. These are the major research projects I have undertaken:

a. Master's Thesis on Communication and Cognition in a Virtual Class: My master's thesis on global online learning (Johri, 2002b) and investigated the relationship between communication and cognition through an analysis of online chat transcripts, interviews with students and faculty, and observation of

Comment [A37]: Why me – the justification for it. It's a personal choice how far back to go to make the case. In my case it worked in my favor as there was a clear trajectory. If that is not the case, you need to justify accordingly.

in-class sessions. Using Activity Theory as a framework I outlined the inherent differences in perspectives brought by students from the U.S. and Russia and linked it to cognitive and collaborative breakdowns (Johri, 2006a; 2005a; 2005d; 2003; 2002a). The project also resulted in software to help students visualize online interaction patterns more easily (Avery et al. 2005; Civjan et al. 2002).

b. Cross-National Learning and Ethnocentrism in Global Teams: I was the graduate research assistant on a large-scale qualitative study of global software development teams in two firms that examined how developers collaborated across national boundaries. I conducted over 40 interview and 2 months of field observations in India, Germany and the U.S. This study led to my qualifying paper and preliminary data for my dissertation proposal (Johri, 2006b; 2005b; 2005c; 2005d). A grant that I wrote based on this study with my advisor funded my dissertation work (Hinds & Johri, 2004).

c. Dissertation Research on Impression Formation among Distributed Workers: My dissertation was ethnographic study of a R&D laboratory with offices in the U.S. and Japan (Johri 2007a). The lab did research in the area of information systems and communication and media technologies. The objective of the study was to understand how coworkers in different locations form interpersonal impressions of each other. The findings established that workers in different locations found it much harder to form useful and usable impressions of their coworkers due to lack of information but equally because of the interpretive differences that led to unbalanced standards for judging people (Johri, 2009b; 2008a; 2008b; 2006c).

d. Informal Interaction in Global Teams: In this recent study I examined informal communication and technology use within a large global IT firm. Data collection through interviews and observations took place in the U.S. and Ireland. Several informants were in England, France, and Japan and necessitated data collection through teleconferencing. Findings emerging from this study indicate that multiple communication channels are essential for work coordination and that technologies such as IM and IRC are replacing informal water cooler conversations (Johri, 2009a; 2009c; 2009d).

7.2 Prior Teaching and Advising Experience

In addition to research, I have also initiated a course **"Global Engineering Work Practices.**" I offered it as a special topics course in Spring'09 and it is currently under review by the course committees at both the graduate and undergraduate level for a regular offering. I have also been invited to give talks on global work several times as part of other course offerings. I also teach sections of the **freshmen engineering course "Engineering Explorations"** and have introduced aspects of globalization in that course. I also teach courses on **"Ethnographic and Qualitative Research Methods"** and **"Foundations of Engineering Education"** at the graduate level. This study will build on and contribute to these courses and to graduate training in the department. I have established a research laboratory called ***tools*LAB** (**t**echnology, **o**pen **o**rganizing, and **l**earning **s**ciences **lab**oratory) whose primary focus is the study of new forms of organizing – particularly global work – and its relationship with learning and education. Currently the laboratory has four student researchers – three graduate students Student 1, Student 2, Student 3 and one undergraduate student. I am also on the dissertation committee of XYZ (Stanford University). Students at ***tools*LAB** are publishing and presenting our research extensively (citations) and alumni are gainfully employed in the industry or at prestigious internships such as the NASA Summer Scholars program.

Comment [A38]: Comprehensive contribution and not just research.

8. PRIOR NSF FUNDING AND RESULTS

I am currently the PI on two recent awards from NSF through the CreativeIT program (IIS-0757540, 2008-2010) and Engineering Education (EEC-0835892, 2009-2010). The grants currently support two graduate students, one undergraduate student, and we will be joined soon by a post-doctoral scholar. On the CreativeIT grant we have done substantial work studying creativity and use of technology in engineering design projects. The work is being presented at Frontiers in Education (Goncher et al., 2009; Pembridge et al., 2009) and Creativity & Cognition (Johri, Chen & Lande, 2009) and being submitted for journal articles. On the EEC grant we are researching and evaluating the advising process and redesigning it with the help of technology. We are also undertaking theoretical work on understanding how online communities are formed by studying Open Source and Wiki communities. I am also Co-PI on a grant (EEC-0832002) that organizes the NSF Awardees Conference for the EEC division. I am responsible for the entire submission and review process of the abstracts which I hosted through the Open Source software Open Conferencing Systems.

9. INTELLECTUAL MERIT

a. This research contributes to a critical area of engineering education and fills a significant gap in our understanding of global engineering work. Findings from this study will provide a foundational theoretical base to develop innovative pedagogical resources to prepare global engineers.
b. Four specific research questions have been derived from the literature and prior work by the PI and are significant for the field and theoretically and empirically grounded. Their examination and subsequent findings are a true interdisciplinary undertaking and will make significant contribution to theory in engineering education, learning sciences, organization studies, and technology studies.
c. The PI has extensive research and work experience in the proposed area of research and is well trained in field research. The PI has previously conducted four research projects in the area of global learning and global work. He has also successfully developed the research and teaching support at the current institution to ensure the undertaking of a 5-year long CAREER research and subsequent research that builds on it. Moreover, this work is integrally connected to the institutional mission.
d. The research and education plan for the study is clear and addressable. Integration of research and education is central to the execution of the project and the cases and curriculum are theory driven and give back to theory building. This approach has already been piloted by the PI with success. This work will display by example how overarching guidelines such as those in the Engineer of 2020 can be successfully connected to theories on how people learn.
e. There is a strong dissemination plan that will make significant use of online resources and repositories. This proposed work fits well with PI's other research project and is integral to a strong research program being developed by the PI.

10. BROADER IMPACTS AND DISSEMINATION OF RESULTS

This project will have significant **broader impact on society** by increasing our understanding of global issues, issues of international diversity, and collaborative work and through its application in undergraduate and graduate courses. For instance, through a better understanding of how to align ones' perspectives with other team members and work across diverse boundaries using technology students will gain crucial interpersonal skills for a global work environment. Lifelong learning on the job and awareness of ethical concerns are other key issues they will learn about. The project will contribute to **building an infrastructure for research and education** as the modular format of the curricular product will allow the use of case studies in our freshmen courses, which I co-teach, and reach around 1000 students each year. In addition, through the "Global Engineering Work Practices" course it will impact additional 50 students (undergraduate and graduate). My close collaboration with Study Abroad and other programs at Virginia Tech will **broaden participation** of diverse groups with international issues and lead to more engagement with students. Through the Office of International Research, Education, and Development (OIRED) at Virginia Tech I will have access to other similar programs and this work will be disseminated to them. My collaboration with the industry will ensure that I am able to impact professionals. An easy-to-use guide on working on global engineering teams will be developed and disseminated broadly to practitioners, policy makers, administrators, students, and faculty.

The findings from this work will be disseminated through journals (e.g. Journal of Engineering Education, Journal of Learning Sciences, Organization Science) and conference venues where the PI and his students regularly present their work e.g. Frontiers in Education (FIE), Annual Meeting of the American Society for Engineering Education (ASEE), International Conference of the Learning Sciences (ICLS), Computer-Supported Collaborative Learning (CSCL), the Annual Meeting of the Academy of Management (AoM). The PI has conducted several successful workshops and symposia (Evans et al., 2008; Newstetter et al., 2008; Johri & Wulf, 2007) and will also disseminate findings in a more interactive manner through workshops and special sessions at conferences. More importantly, the case studies, case preparation kits, and curriculum developed through the project will be released online under a Creative Commons License (in addition to case study being published as a book). This will disseminate not just a teaching method, but approaches to evidence-based instruction and assessment, a goal of both ABET and the engineering education community. The PI is well experienced in the use of technology for learning and for dissemination and will make efficient use of online channels for this purpose. In addition to hosting it on a dedicated site, the materials will be hosted on Needs (http://www.needs.org/needs/) and Pathways site (http://www.engineeringpathway.com/ep/), GlobalHUB, NSDL and other successful outlets. Different dissemination methods will allow users to be able to personalize the materials suitably.

11. ALIGNMENT WITH INSTITUTIONAL MISSION

Comment [A39]: Important for a CAREER award.

My work has substantial support from Virginia Tech. **International and global issues** form a core component of the strategic mission of the University, the College of Engineering, and the Department of Engineering Education (see letters). Virginia Tech has invested and continues to invest substantial resources in the efforts to globalize and internationalize its education and presence. My research contributes directly to these efforts. The interest in global and international issues at the institutional level is also reflected in **outreach** efforts such as OutreachNOW where the main topic for this year is international aspects of curriculum and research at Virginia Tech and I am presenting my work there (http://www.cpe.vt.edu/outreachnow/). In addition, Virginia Tech is making substantial efforts to make its engineering **curriculum** more humanistic through a core "Curriculum for Liberal Studies" and the course I offer will adhere to their guidelines and will also be listed as part of their offerings (http://www.cle.prov.vt.edu/). The results of this work also align with another key component of the institutional mission here at Virginia Tech – **diversity**. I am a member of the Committee for Equal Opportunity and Diversity, which reports directly to the University Council, and I represent the international community (http://www.governance.vt.edu/comeod/). In recent years, international diversity and concerns of the international community have become a central issue at Virginia Tech and my research and service work align closely with these efforts. This research and education plan also supports the **innovation** mission of Virginia Tech through collaboration with the Corporate Research Center as a research site and as a site for dissemination. Finally, I am an affiliated faculty with the Human-Computer Interaction Center in the department of Computer Science and have a courtesy faculty appointment with the Industrial and Systems Engineering department. I also regularly engage with faculty in School of Education and Science and Technology Studies furthering the mission of Virginia Tech to become more **interdisciplinary** in its approach.

12. ADVISORY BOARD

In addition to my colleagues in the Department of Engineering Education, five highly-regarded researchers and educators have generously agreed to serve on the advisory board for this project (see letters). They bring expertise in disciplinary issues, learning sciences, industrial relations, engineering studies, and implementation and assessment of international programs.

[NAMES REMOVED FOR PRIVACY – THEY WERE BOTH FROM VT AND OTHER INSTITUTIONS]

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Budget Impact Statement (Due to reduction in budget at the time of award)

The reduction in budget is around 20% of the original proposed budget. The revised budget has been achieved by reducing faculty salary, student funding, and travel budget. Corresponding to this decrease in budget, the effort and output of the proposed research is being reduced. The number of interviews to be conducted will be reduced from 120 to 90 and the number of survey participants will be reduced from 250 to 175. This will result in 8 case studies. The quantity of data collection will be reduced without compromising the quality of results and findings.

CAREER: INVESTIGATING GLOBAL ENGINEERING WORK PRACTICES

REVIEWS

Comment [A42]: This gives an indication of what reviewers are looking for in a proposal but are also reflective of the nature of review panel. Remember, this was in 2009 and now the panel will be quite different.

Proposal Number: 0954034

Panel Summary:
Panel Summary

Intellectual Merit

The panel agreed that this was a very timely proposal and covers an area that is extremely important to current and future engineering students. We often don't teach students how to work, and global (potentially virtual) groups are new enough that we don't know how to teach needed skills for globally extended teams and projects. The panel felt that the proposed work would open a new window into globablization by rigorously examining practice as a means to impact future engineers.

There was some discussion about how well grounded the proposed research plan was. Some panelists thought that the exploratory research conducted through case studies would provide valuable insights into developing a rigorous theory about globalized workplaces. Other panelists felt that the proposal claimed that theoretical understanding would be developed, but the proposal did not outline how this would occur. Overall the consensus was that valuable insights into globalized engineering work would be generated by this research. There are insights that will likely be developed by the case study collection that may be much broader than the PI outlined in the proposal. Strong mentoring and communication with a broader community is thus critical to the PI's professional development. The panel felt strongly that adding members from industry, and not just academia, would strengthen external review of the PI's work.

Broad Impact

Overall the panel was impressed by the plans to disseminate the case study collection both through a traditional book and through open-source initiatives. The case study collection will serve as a good resource for teachers. The PI is cognizant of diversity issues, and the case studies may bring to light new issues in diversity, particularly in regards to global collaborations.

One criticism of the panel is there is not a clear pathway from research to action outlined in the PI's career plan. How will you use the results of this study to directly impact students yourself? What actions are planned to make sure the lessons from this research are integrated into curricula around the country? How will you change the culture? While these are not pressing concerns for early career faculty, they should guide professional development.

Department Chair's Letter

The support offered by the department is sufficient, but a clearer plan for mentoring the PI needs to be implemented, particularly given the breadth and potential of this research. Due to the large amount of international travel required for this research, a clearer statement of departmental support for this travel would have strengthened the proposal. Similarly a

clearer plan for mentoring would have been desirable.

Recommendation

Overall a very well written and timely proposal that will provide valuable insight on how we can better prepare students for globalized work environments. The panel concurs that the proposal should be highly recommended for funding.

HIGHLY RECOMMEND

Panel Recommendation: Highly Recommend

Review #1

Proposal Number:	0954034
Performing Organization:	VA Polytechnic Inst
NSF Program:	Engineering Education
Principal Investigator:	Johri, Aditya
Proposal Title:	CAREER: INVESTIGATING GLOBAL ENGINEERING WORK PRACTICES TO PREPARE 21st CENTURY ENGINEERS
Rating:	Excellent

REVIEW:

What is the intellectual merit of the proposed activity?

This proposal will look at how engineering practices have changed due to globalization and how engineers work on global teams. The proposer makes a very important point that workplace related studies are poorly represented in the literature associated with engineering education in spite of the fact that our profession is become more global in nature. Thus this proposed research seems quite timely as it seeks to fill a gap in the body of knowledge associated with engineering education. Specifically, the research will focus on the questions: 1. How does team diversity impact alignment of perspectives among the global team members? 2. How does technology impact work coordination for global teams? 3. What informal learning practices do engineers develop and us in their work on global teams? and 4. What personal and ethical dilemmas do global engineers encounter in their teamwork?

The investigator is hoping to develop a body of knowledge relating to global engineering teamwork using this 5 year research project. The mixed-method data collection process to be employed in this work will collect data by interviews with 40 informants each year for the first thee years of the project. Surveys using social networking and construct validation will be employed to assess the validity of the data provided by the interviews. In addition to the 120 informants, an additional 250 participants will be recruited for input to the research.

The investigator seems uniquely well qualified to undertake this study and currently has two recent awards from the NSF on related topics.

The outcomes of this work will be reported as published guides and presentations that will be distributed to practitioners, as published case studies to be used in courses and workshops, and as case preparation kits to be used in courses and workshops. In all, the dissemination plan seems fairly comprehensive and highly useful.

An important strength of the project is that it will utilize an advisory board consisting of five experts in this field. It would appear that all five of these people are engaged in some aspect of the academic enterprise. The advisory group might have additional strength if it were to include practicing professions from international corporations who have led global engineering teams.

The timeline for the project listed in the proposal seems appropriate in scope and content. There would appear to be sufficient access to the resources needed to complete this project.

What are the broader impacts of the proposed activity?

This project, if successfully carried to completion, should provide a knowledge base that could be very useful to the education of the next generation of global engineers. It will also contribute to the building of an infrastructure for future research and education. The modular format of the curricular products from this study could be widely useful by engineering programs in the U.S.
The investigator expects to publish the findings of this study in reputable engineering education journals and in venues such as the FIE conference and the ASEE annual conference. Even more important than the journal articles, the case studies produced by this work should be a valuable resource to those who wish to include information on global teams in their courses. The inclusion of ethics as a research question is a particularly useful topic in this study.

Summary Statement

Unlike many proposals for educational innovation, this particular project is very practical in nature and should provide outcomes that are broadly applicable. While both of the NSF criteria for evaluating proposals are of importance to my evaluation of this proposal, my ranking is a reflection of the unique nature of the study. I am convinced that the experience and enthusiasm of the investigators will be a contributing factor to the overall success of this project.

Review #2

Proposal Number:	0954034
Performing Organization:	VA Polytechnic Inst
NSF Program:	Engineering Education
Principal Investigator:	Johri, Aditya
Proposal Title:	CAREER: INVESTIGATING GLOBAL ENGINEERING WORK

CAREER: INVESTIGATING GLOBAL ENGINEERING WORK PRACTICES

PRACTICES TO PREPARE 21st CENTURY ENGINEERS

Rating: Excellent

REVIEW:

What is the intellectual merit of the proposed activity?

Intellectual merit of the project is that it advances and breaks new ground by developing a theoretical foundation of pedagogy and content for educating engineers with global competence and implementing those principles in a representative model course. In particular, the project proposes to use authentic practice of globally based engineers to study the effect on teamwork for dimensions of diversity, technology, informal learning, and ethics. The project's goals align well with one of the major framing principles of the book, The Engineer of 2020, which broadly discusses the need for engineering education to prepare students for work in a global context. The proposer is very well qualified as shown by prior and ongoing work and publications in the areas of teamwork and technology in a global environment. His work is creative, original and potentially transformative as demonstrated by the research questions and plans synthesized from his comprehensive literature knowledge, interactions with engineering teams working in a global environment, and the content, pedagogy, delivery and assessment of a course he developed, "Global Engineering Work Practices." The project's assessment plan is particularly thorough and detailed, although concept assessment of student learning in his course is not detailed and could increase impact if it was well developed. As such creating a reliable and valid instrument to measure knowledge and understanding of global workplace practice would be valuable contribution engineering education assessment. The project is very well conceived and well organized as demonstrated by a well articulated 5-year plan and pathway marked by critical milestones of progress. There is good access to resources including required equipment, workspace, well qualified graduate students, and high quality undergraduates.

What are the broader impacts of the proposed activity?

Broader impacts of the project are that it will advance discovery and understanding of the theory and practice of teaching and learning of the nature of global engineering work practice, including its opportunities and its issues. While a large body of students at Virginia Tech will have the chance to learn and understand global team practice (50 graduates and 1000 undergraduates per year), this project's web-based research results and course materials and assessments will promote a much broader opportunity for national and international engineering instructors to infuse the subject into their curricula. The opportunity for participation of underrepresented groups is not just routinely addressed in this proposal, but is highlighted as one of the four major research questions of the project "How does team diversity affect alignment of perspectives among global engineering team members?" The project will help build infrastructure and enhance networking opportunities first, through a wide variety of collaborative contacts and the outstanding advisory board members, and next with the additional possibility of developing contacts and collaborators through the well designed web based dissemination of the project's results and materials for research and education. Dissemination additionally will also occur through workshops, publications, presentations, as well as digital distribution sites that include Needs, Pathways, GlobalHUB, and NSDL. Societal benefits would include graduating undergraduate and graduate students who are better prepared to compete effectively in a diverse, rapidly-changing global engineering workplace with the hope of maintaining and improving the

quality of life in the US and abroad as well.

Summary Statement

The Department Letter by the head makes a strong commitment to the proposer's mentoring by experts locally and nationally through travel funding and by supporting travel to national conferences and by continuing to build and strengthen the engineering education program at Virginia Tech. He also intends to keep teaching load as low as possible.

Overall this is an excellent proposal that strongly addresses national needs in the important and growing area of the engineering global workplace. It does so also from the viewpoints of the theoretical foundation as well as course design, delivery, and assessment in the subject of Global Engineering Work Practices. The proposer's prior work, his creativity and originality, his research plan and assessment methodology, and his collaborations and dissemination plan are all also of the highest quality, thus giving this project the possibility of a truly transformative impact on engineering education and practice.

Review #3

Proposal Number:	0954034
Performing Organization:	VA Polytechnic Inst
NSF Program:	Engineering Education
Principal Investigator:	Johri, Aditya
Proposal Title:	CAREER: INVESTIGATING GLOBAL ENGINEERING WORK PRACTICES TO PREPARE 21st CENTURY ENGINEERS
Rating:	Excellent

REVIEW:

What is the intellectual merit of the proposed activity?

This project addresses an important issue that is raised in most of the recent calls for revitalization of engineering education: globalization. In the current world there is little doubt that globalization issues must be dealt with. The path of dealing with globalization is to focus on the current workplace through largely an interview methodology, develop materials around four key dimensions, and them disseminate the materials back into the educational environment.

The prior work of the PI is very relevant and appears to be of high quality. The PI appears to be fully capable of executing the plan of study that proposed.

The proposal is narrowly transformative in that successful results will produce course materials and curricular materials which could be widely used.

The PI has access to adequate resources in general, and is strongly supported by his departmental chairperson. There is a concern I have in the chairperson's statement that he will keep the teaching load on the PI "as low as possible" during the grant. It would be

better to have a firm commitment on teaching load with an escape clause should economic or other conditions demand revision. My concern is with the large amount of travel that will be necessary to support the research plan. The project timeline as 40 interviews in two summer months. That would average five interviews per week, one interview each day. That schedule for the summer may prove to be difficult to implement. Moreover, the amount of travel funds requested appear to be minimal.

What are the broader impacts of the proposed activity?

Successful completion will advance discovery by opening a window on an untaped source of globalization data - actual workplace data. This should be obvious, but in retrospect, and based on the content analysis by the PI of recent ASEE and FIE papers, the academic community has not utilized this data resource. The concept of developing case based or problem based exercises is very good and could help to widely disseminate the results of the project.

However, the PI does not identify the web-based repositories for PBL as a dissemination target, which is curious.

The proposed project does not address directly issues of unrepresented groups. Nor does it have a well developed proposal for mentoring of graduate students who are part of the project.

Summary Statement

The proposed project is well defined and fits well with the PI's past research and his future goals. It draws on an untapped resource - workplace practice in global engineering teams. And by ethnographic methodology develops a set of course/curricular materials which could find an important place in engineering curricula.

The PI might investigate the use of the findings from the research to develop game approaches that could be very useful course materials especially for early engineering education.

Review #4

Proposal Number:	0954034
Performing Organization:	VA Polytechnic Inst
NSF Program:	Engineering Education
Principal Investigator:	Johri, Aditya
Proposal Title:	CAREER: INVESTIGATING GLOBAL ENGINEERING WORK PRACTICES TO PREPARE 21st CENTURY ENGINEERS
Rating:	Excellent

REVIEW:

What is the intellectual merit of the proposed activity?

CAREER: INVESTIGATING GLOBAL ENGINEERING WORK PRACTICES

This proposal seeks to investigate the work practices of engineers on global teams in order to better integrate the skills necessary to support those practices in to the engineering classroom. This is an important topic on every engineering campus. The PI has the background and connections to successfully complete this proposed research. Additionally, he has selected an appropriate advisory board for the project. The research questions are well defined and grounded in the literature. The research methods are well conceived and planned. The PI is leveraging the work of others collecting data in similar veins to use their already validated survey instruments. The PI's use of archival materials is appropriate, though it is hoped that the PI will not under-estimate the use of the organizational artifacts in his data analysis.

What are the broader impacts of the proposed activity?

The PI's plan to integrate research and education (education plan) is clever and flows naturally from the research proposed. His articulated assessment plan for the education activities is based on his previous work. This reviewer hopes that the PI will publish his *method* for case preparation kits along with his results; the PI is encouraged to consider fields beyond engineering such as management or instructional development. This plan would benefit, however, from a systematic investigation of how different groups of students are impacted by the pedagogical choice - does it play in to retention? If so, for whom?

The PI articulates a good dissemination plan, including a broad plan for disseminating the proposed multi-disciplinary work.

Summary Statement

Overall, this is an excellent proposal. The topic is important and timely. The research is well articulated and appropriate. The education plan flows naturally from the research work and will be assessed using methods the PI has successfully used in prior work.

The PI's department chair promises financial support and mentions mentoring from senior faculty at the PI's institution and at other universities.

Review #5

Proposal Number:	0954034
Performing Organization:	VA Polytechnic Inst
NSF Program:	Engineering Education
Principal Investigator:	Johri, Aditya
Proposal Title:	CAREER: INVESTIGATING GLOBAL ENGINEERING WORK PRACTICES TO PREPARE 21st CENTURY ENGINEERS
Rating:	Very Good

REVIEW:

What is the intellectual merit of the proposed activity?

CAREER: INVESTIGATING GLOBAL ENGINEERING WORK PRACTICES

This proposal will look very broadly at how globalization has impacted the work habits and opportunities of practicing engineers. The research questions focus on aspects of engineering work done on global teams; the questions seem timely since an increasing number of engineers are working across time zones on a regular basis. To answer the research questions the PI will develop a collection of case studies. The main deliverables of this project are a theoretical understanding of global teamwork and pedagogical strategies based on this theory.

It is not clear from the proposal the form the theoretical understanding of global work habits will take nor how this understanding will can impact practice. To this reviewer there was a chasm between the good work of case study development and how these case studies would lead to theoretical understanding that the proposal did not successfully bridge. The lack of details on the theory leaves some of the rest of the claims of the proposal unjustified.

It is not clear if the budget is adequate for the large amount of travel that this proposal seems to require, particularly international travel.

What are the broader impacts of the proposed activity?

The proposal does a good job of making the results of the research available to a broad audience. Since the research questions are focused on teamwork they have the potential to impact how students are taught in engineering programs. The case study book and guide for working on global teams will likely have broad impact as well. Beyond the dissemination of the case studies the rest of the dissemination plan is fairly standard. It is not clear from the proposal what the overall plans of the PI are to develop his teaching portfolio or his long term plans for how this research will shape his career.

The proposal does not specifically address how the research and teaching plan will address groups that are traditionally underrepresented in engineering. Given the opportunity to look at issues that affect underrepresented groups globally by looking at cases of underrepresented engineers across cultures this seems to be an opportunity the proposal misses.

Summary Statement

Does the institution commit to the professional development and mentoring of the PI? To some extent. The support letter from the department head commits to providing equipment, summer salary support, and some funding for graduate students and travel. Indirect cost return will also be provided to the PI. It should be noted that a firm dollar amount or upper limit is not given which makes the promise of support somewhat open to future interpretation. The department head seems committed to mentoring this faculty member by funding opportunities for travel, however it is not clear what dollar amounts of travel will be supported.

Review #6

Proposal Number: 0954034

Performing Organization: VA Polytechnic Inst

CAREER: INVESTIGATING GLOBAL ENGINEERING WORK PRACTICES

NSF Program:	Engineering Education
Principal Investigator:	Johri, Aditya
Proposal Title:	CAREER: INVESTIGATING GLOBAL ENGINEERING WORK PRACTICES TO PREPARE 21st CENTURY ENGINEERS
Rating:	Excellent

REVIEW:

What is the intellectual merit of the proposed activity?

Overall, this is a well thought out proposal for gathering information and lessons-learned about how already existing distributed teams function. Once this data has been gathered, the PI proposes to develop a theoretical understanding of global engineering work and disseminate these results.

The data gathering and the final dissemination efforts are very plausible, but the ability to develop a theoretical model may not be. The reason is the wide variety of team structures, team goals, etc that already exist -- even within a single field such as software development. Thus, there may be an overwhelming set of data with no way of detrmining which type or team/process actually works well. It is stil vitally important that the data gathering stage take place, so this is an important effort

What are the broader impacts of the proposed activity?

The proposal addresses the broadest population possible; namely, engineers around the world and in all different fields.

Summary Statement

Overall, this is an excellent proposal that could point the way toward curricula that prepare students for this very complex workplace of the future.

CAREER: INVESTIGATING GLOBAL ENGINEERING WORK PRACTICES

PUBLICATIONS BASED ON CAREER RESEARCH

BOOK

B1. Johri, A. & Sharma, A. (2013). *Designing Development: Case Study of an International Education and Outreach Program*. Morgan & Claypool Press, San Rafael, CA.

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JOURNAL PAPERS

J9. Johri, A. (2015). Impressions in Action: The Socially Situated Construction of Expertise Impressions in the Workplace. *Journal of Organizational Ethnography*, 4(1): 44-63.

J8. Sharma, A. & Johri, A. (2014). Learning and Empowerment: Designing a Financial Literacy Tool to Teach Long-term Investing to Illiterate Women in Rural India. *Learning, Culture & Social Interaction,* 3, pp. 21-33.

J7. Liu, X., Wang, G. A., Johri, A. Zhou, M., & Fan, W. (2014). Harnessing Global Expertise: A Comparative Study of Expertise Profiling Methods for Online Communities. *Information Systems Frontiers*, Vol. 16(4): 715-727.

J6. Mitra, R., Johri, A. & Nov, O. (2013). Effect of External Events on Newcomer Participation in Open Source Online Communities. *First Monday*, Vol. 18, No. 6, 3-June-2013.

J5. Johri, A. & Nair, S. (2011). The Role of Design Values in Information Systems Development for Human Benefit. *Information Technology and People*, Vol. 24, Issue 3, 281-302.

J4.Johri, A. (2011). Sociomaterial Bricolage: The Creation of Location-Spanning Work Practices by Global Software Engineers. *Information and Software Technology*, 53 (9): 955-968.

J3. Johri, A. (2010). Open Organizing: Designing Sustainable Work Practices for the Engineering Workforce. *International Journal of Engineering Education*, 26(2):278-286.

J2.Johri, A., & Teo, H. (2012). Assessing the Effectiveness of Open Organizing as a Model for Re-designing Design Learning. *International Journal of Engineering Education*, Vol. 28, Issue 2, pp. 374-380.

J1. Johri, A. & Pal, J. (2012). Capable and Convivial Design: A Framework for Designing Information and Communication Technology for Human Development. *Information Technology and Development*, 18(1): 61-75.

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CONFERENCE PROCEEDINGS

C11. Johri, A. (2018). Lifelong Learning Ecology of FLOSS: Participatory and Personalized Learning Over Time and Space. *Proceedings of ACM OpenSym Conference on Open Collaboration 2018*.

C10. Johri, A. & *Teo, H. J. (2018). Achieving Equilibrium through Coworking: Work-Life Balance in FLOSS through Multiple Spaces and Media Use. *Proceedings of ACM OpenSym Conference on Open Collaboration 2018*.

C9. Kusano, S. & Johri, A. (2015). Developing Global Engineering Competency through Participation in "Engineers Without Borders". *Proceedings of ASEE 2015*.

C8. Johri, A. (2015). Sociomaterial Bricolage: Engineering Learning as the Practice of Making Sense by Making Do. *Proceedings of CSCL 2015*.

C7. Johri, A. (2015). Digital Materiality as the Fabric for Socio-Temporal Organizing of Learning: A Case Study of Open Source Software Development. *Proceedings of CSCL 2015*.

C6. Johri, A. (2015). Supporting Global Virtual Work through Blogs and Micro-Blogging. *Proceedings of HICSS 2015*.

C5. Chowdhury, B., Kusano, S., Johri, A. & Sharma, A. (2014). Peer Scaffolding in an Interdisciplinary Studio-based Design Course. *Proceedings of ASEE Annual Conference 2014*.

C4. Johri, A. & Srinivasan, J. (2014). The role of data in aligning the 'unique identity' infrastructure in India. In *Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing (CSCW '14)*. ACM, New York, NY, USA, 697-709.

C3. Srinivasan, J. & Johri, A. (2013). Creating machine readable men: legitimizing the 'Aadhaar' mega e-infrastructure project in India. *In Proceedings of the Sixth International Conference on Information and Communication Technologies and Development*. ACM, New York, NY, USA, 101-112.

C2. Johri, A. & Sharma, A. (2012). Learning From Working on Others' Problems: Engaging Students in Long-term Global Projects for Reciprocal Learning. *Proceedings of ASEE Annual Conference 2012*.

C1. Johri, A. (2011). Look Ma, No Email! Blogs and IRC as Primary and Preferred Communication Tools in a Distributed Firm. *Proceedings of the ACM Conference on Computer Supported Cooperative Work*, March 2011, pp.305-308. (Best Note Award)

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JOURNAL SPECIAL ISSUE EDITED

E1. “Engineering and the Workplace,” double theme issue of Engineering Studies “the Journal of the International Network of Engineering Studies, Published: Dec. 2010 & August 2011, 7 articles; 3 articles in the Top 10 most cited articles in the journal.

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BOOK CHAPTERS

BC4. Johri, A. (2014). Engineers' Knowing in Practice: Reconciling Sociality and Materiality through Action. Fenwick, T. & Nerland, M (Eds.). *Reconceptualising Professional Learning in Turbulent Times: changing knowledges, practices, and responsibilities*, Routledge.

BC3. Johri, A. Using Qualitative and Ethnographic Research Methods to Conduct Interpretive Research in Engineering Education. Johri, A. & Olds, B. (2014). The *Cambridge Handbook of Engineering Education Research*, Cambridge University Press, New York, NY, pp.571-570.

BC2. Johri, A. & Jesiek, B. Global and International Issues in Engineering Education. Johri, A. & Olds, B. (2014). *Cambridge Handbook of Engineering Education Research*, Cambridge University Press, New York, NY.

BC1. Stevens, R., Johri, A. & O’Connor, K. Professional Engineering Work. Johri, A. & Olds, B. (2014). The *Cambridge Handbook of Engineering Education Research,* Cambridge University Press, New York, NY.

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PRESENTATIONS

P5. Johri, A. (2014). Technology as catalyst and context: Global software development through Postcolonial Third Spaces. Position paper for Workshop on Global Software Development in a CSCW Perspective, February, Baltimore, U.S.

P4. Johri, A. & Sharma, A. (2011). Designing for Development: Three Preliminaries Studies from Field Research in India. Workshop on Mobile Collaboration in the Developing World at ACM CSCW 2011, March 20, 2011.

P3. Johri, A. (2010). Leveraging the Digital Media Ecology in a Distributed Firm. Presented at the International Symposium of Information Systems, Hyderabad, India, Dec. 18, 2010.

P2. Johri, A. (2009). Using Case Studies and Case Preparation Kits to Teach Global Team Competency. Poster Session at the 12th Annual Colloquium on International Engineering Education, Ames, Iowa October 22-25, 2009.

P1. Johri, A. (2009). Multiplicity and Personalization: How Global Engineers Develop Successful Technology-Mediated Work Practices, 12th Annual Colloquium on International Engineering Education, Ames, Iowa October 22-25, 2009.