NAVIGATING OPEN INNOVATION: AN EXPLORATION OF HIGH-TECHNOLOGY ENGINEERING IN PRACTICE

A thesis presented

by

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Abstract

This study explores the authentic practice of high-technology invention and development of products and solutions. The research focuses on how high-tech engineers describe their own experiences practicing innovation and development. Narrative inquiry enables access and understanding to these lived experiences through the research participants’ own voices, organizational contexts and artifacts.

The study uses a composite framework in order to achieve the necessary explanatory scope. Chesbrough’s Open Innovation (2003) and Miller et al.’s (2006) extended explore/exploit knowledge curation dynamic is combined into a new theoretical framework, OI (E^2D). A combination of semi-structured interviews and writing prompts enables data collection and analysis of what is of interest. Findings are identified and presented, and conclusions and recommendations for further research are drawn.

Keywords: High-Technology, Open Innovation, Knowledge Curation, Organizational Theory, Computer Engineering, Invention
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Il mio professori, dal mio cuore ti ringrazio. Per favore continua a insegnarmi!
Dedication

This doctoral thesis is dedicated to Kathleen Mary, love of my life and mother of the two finest men I ever met, Drew and Dylan:

Amor omnia vincit;

ut tibi omnia mea

Porticus ad vis muralibus?

Bright blue eyes that laugh;

You think therefore we are.
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CHAPTER 1: INTRODUCTION

This doctoral thesis focuses on the practical, lived experiences of high-technology engineers as they wrestle with innovation and development practice. Technologies that shape our immediate vistas and sketch out the landscape of our future are the scope of their practice. This chapter begins with a statement of the problem and examines it in depth, addresses significance of the research, and then discusses the theoretical framework and its explanatory power in context.

Statement of the Problem

The topic. Advanced computer and electronics automation as high-technology is often promoted as a futuristic means to usher in a better tomorrow for all with magical, push-button ease. In reality, it is often a narrow vehicle for opportunistic profit for an elite few (Haragadon & Martin, 2012; Lee, Kim, & Kim, 2012). Somewhere within the pursuit of income and the latest smartphone craze, the quest for profit and gain can be directed to stimulate the global economy while solving socially relevant challenges common to all (Hishida, 2013; Riedl, 2013; U.S. Subcommittee on Technology and Competitiveness, 2006). Technological invention and creative insight as socially just innovation can be that means, today.

It may potentially be that, but it is also commerce and business rooted in the social and economic problems of the now (Tucci, Chesbrough, Piller, West, & Fe, 2016). Hinging on the transfer of marketable need to idea to product, how that invention and development happens, how the technology comes to be, how the magic is made is as much accidental art as it is reflective, practiced and inclusive science (Haragadon & Martin, 2012; Lee et al., 2012).
It is responsive, agile, innovation, invention, and development of technology as relevant solutions that fuels the business of high-technology in the 21\textsuperscript{st} century (Abebe & Angriawan, 2014; U.S. Subcomittee on Technology and Competitiveness, 2006; Weiss, 2014). This necessary agility and adaptation is problematic for large, well-established corporations rooted in successful implementation, identified market share, and a minimally diverse but highly credentialed and knowledgeable work force. They are often at siege in a world growing more and more comfortable with crowdfunding du jour and entrepreneurs from anywhere with the next big idea (Booth, 2015; Ingram, Teigland, & Vaast, 2014; Langley, 2015).

Simply forensically measuring patents, twitter feeds, web site hits, and downloads cannot reveal what makes successful, resonant invention and innovation happen, just that it did or did not happen. The difference between understanding how to go about it, and just hoping for successful invention and development to happen is the dividing line between success and failure in the business of technology (Drucker, 1993; Tucci et al., 2016).

That makes understanding how technical innovation is actually experienced in practice critical to practicing it well. Efforts in meta-innovation, such as Chesbrough’s Open Innovation model (OI), focus on technology as effective business practices that are organic, inclusive, and adaptive (H. Chesbrough, 2003, 2015; H. Chesbrough & Brunswicker, 2014). The impact, the cumulative effect of engineers’ experiences, perspectives, and ways of understanding their own constructs of technology is central to the organic and adaptive practice of technological development.

**Research problem.** Our collective capacity to shape and be shaped by our technologies at this moment in our history is uniquely enabling. Our collective responsibility to
each other to justly include all perspectives is inescapably aligned to that emergent potential. Thus, the impetus for the research problem: To explore high-technology engineer’s authentic experiences practicing agile, profitable, inclusive, and relevant invention and development through their own voice, organizational contexts and artifacts.

**Justification for the research problem.** Complex electronic devices and software solutions as technological artifacts are the product of the work of high-technology business driven by the shift of ideas, dreams, and conceptual constructs between engineers (de Alvarenga Neto & Choo, 2011; March, 1991; Miller, Zhao, & Calantone, 2006; Nonaka, 1994). The organizational culture, constructs, and contexts that enable or inhibit innovation may be found in the authentic voices of the engineers that work within them (Hazy, Tivnan, & Schwandt, 2003; Schwandt & Marquardt, 2000; Seidman, 2013).

Quantifying collection and calculation of patents relays that some type of innovation and invention has happened. Studying the social constructs that frame actual engineering practice experiences shifts research focus towards how that innovation happens and what conditions and pre-conditions bound the innovation event(s). The business of technology is a very technical and specific business, while remaining the domain of human beings attempting to make sense of their own ideas and positionalities in a fluidly changing knowledge economy (H. Chesbrough, 2012; Drucker, 1993; Inoue & Yang, 2015). The process and makeup of high-technology invention and innovation must not be allowed to remain a mystery if our collective society is to make the right decisions for a common and inclusive future.

Scholarly analysis of this kind of invention shows that the chances of making something truly new, truly significant and relevant to society have always favored outright failure
(Chesbrough, 2003; Gertner, 2012, p. 152). The old perspective on technical innovation was to celebrate the best and the brightest and the privileged elite. Scientists with the best pedigrees of education and mentorship were regularly sought out and recruited into a single organization in one laboratory.

Bastions of privileged thought in this new century make for a siege mentality, incapable of outlasting the agile and adaptive waves of crowdfunding where the market and producer are intimately connected (Agrawal, Catalini, & Goldfarb, 2014; Belleflamme, Lambert, & Schwienbacher, 2014; Riedl, 2013). The assumption that the privileged few must determine our collective future does not address the very idea of an inclusive, collective future.

The parochial isolation of such laboratories reflected the prevailing cultures and times while providing us with unique artifacts in context (Berger & Luckmann, 1966; Bijker, Hughes, & Pinch, 1987; Gertner, 2012; Mousavidin & Silva, 2010). The dialogue of creation and invention was always turned inward, a solipsistic monologue that still managed to produce eight Nobel prizes and Turing awards from Bell Labs alone (Gertner, 2012). But today is not yesterday, and the scope for this study is active practice by actual engineers such that patterns should emerge with insight into the true machineries of technical invention and development in the 21st century.

**Deficiencies in the evidence.** Existing studies discuss knowledge and work contexts, demand-driven markets, policy and licensing influences without attempting to explore the fundamental dynamic of enabling and inhibiting social contexts, factors, and impetus through the perspective of practicing engineers (De Cian, Bosetti, & Tavoni, 2012; Makri, Hitt, & Lane, 2010; Priem, Li, & Carr, 2012; Rizzuto, 2011; L. F. S. Wang & Mukherjee, 2014). Further, the
research emphasis appears to be on external competitive economic factors and innovation results instead of investigating the practice, phenomena and authentically lived contexts that support it. Thus, qualitative inquiry with practicing engineers allows insights into as-is knowledge construction, cultivation, and curation as the potential anatomy of technical innovation in the 21st century.

Relating the discussion to the audience. By examining high-technology engineering innovation practices and experiences through authentic voice, better understanding and mapping of the phenomena surrounding and permeating organic, inclusive, financially successful technical innovation may emerge. By cultivating this understanding, researchers might be able to attempt clean identification of driving and mediating variables that enable successful high-technology innovation and development. Technology firm leaders in turn might better plan and align business strategies that are not just profitable and opportunistic, but also fully inclusive, organic, and beneficial.

Significance of the Research Problem

To fully appreciate the significance of high-technology’s impact, simply step back for a moment and simply imagine daily life without it. No smartphones, no computers, no electronic data to help with doctoral research, a world without any centrally controlled heating and cooling, no nationwide power grid to turn on our lights and televisions. Romanticizing a simple life “off the grid” is a far cry from the realities of our wholly embraced dependence. Emergent technologies are almost uniformly focused on creating a safer, more comfortable existence for ourselves and for our families. In 2015, one-quarter of the global population used smartphones. In 2016, India passed the US with over 200 million smartphone users, and when the US arrived
at that user volume in 2017, that number represented 65% of the total population in the US (eMarketer, 2014). Our collective reliance on technology for day to day existence has become ubiquitous and transparent to us.

Those statics are both engaging and antiseptic in summarizing impact on real, daily life. Something as commonplace as a smartphone is also a lifeline for Syrian and Iraqi men, women, and children refugees and reflects what technology may do in the just service of dispossessed humanity (Witty, 2015). More vital to the oppressed than food, technology in this digital age means survival. Thousands of refugees had perished at sea in this one instance, and one who had survived had readied GPS position and an SOS to send just in case the worst came to pass (p. 57).

The absence of this commonplace, entertaining technology is inconvenient to the privileged but a matter of life and death for the oppressed. Thus, the real significance of technology’s influence on the formation, growth, and interconnection of society in the 21st century emerges. It is not a question of trends and fads; it is a question of enabled, just, and substantive choice.

The matter of this research is exploration on technological invention, adaptation, and creation. Studied with correct rigor and discipline, that practice may enable more socially responsible and inclusive progress. It may enable us to address more weighty issues than entertainment, consumerism, and data backup. If all of society does not choose to wrestle with the challenges of social justice while creating the future through technology, there will be no justice for ourselves or our children tomorrow. The argument could be framed that it is our
ability to consider and act in favor of the greater good that makes us fully human. The need to consider our mutual and collective destinies in light of technology is just such an opportunity.

Technology shapes us as we shape it. High-technology is usually discussed in terms of products and services, business opportunities and commercial growth (Martinez, 2010; Moniz, 2012; Priem et al., 2012; Tucci et al., 2016). Thus, we are fully aware if often forgetful of what technology brings to our tables, homes, and hearths for immediate consumption, survival, and quality of life.

We pursue technological improvements simply because we see opportunity and gain (Breschi, Malerba, & Orsenigo, 2000). Scholarly thought certainly has invested time and energy in the effort of defining patterns of innovation as technological regimes. The inherent assumption(s) prevail even today that economic progress is equivalent to social progress. Do patents and trademarks ensure we feed our hungry, warm those of us who are cold, or educate our children (p. 389)?

If phenomena can be identified that leads to positive, socially beneficial innovation that is also sustainable economically, then we can potentially share a meaningful future through technology. A future that is perhaps more substantial, inclusive, and just than the pursuit of wealth and distracting amusements. Similarly, if the exploration of social, cultural, and organizational factors that inhibit socially relevant innovations in technology is fruitful, then perhaps we can devise a framework that helps us map our way to the future. Perhaps we can help enable better planning and alignment to globally responsible, beneficial pursuits that are financially sustainable. The future is texting us all. What will we contribute to that dialog?
Research Question

The central research question of the study is: *How do high-technology engineers in a global firm describe their own experiences trying to practice agile and profitable invention and development?* The question was constructed to fully explore how the research participants adapted and applied different meaning making and knowledge sharing techniques to influence and integrate their innovative technology ideas within their professional practice (de Alvarenga Neto & Choo, 2011; Denrell & March, 2001; Miller et al., 2006; Tucci et al., 2016).

Appendix E details supporting questions that extend and deepen the core research question in order to enable mapping and definition of interview protocols and more. We now turn attention to the theoretical framework driven by the central question and a focused review of the literature (Chapter 2). The constructed framework serves as this research’s central theoretical lens.

Theoretical Framework

Chesbrough’s Open Innovation (OI) model combines with Miller’s extension of organizational knowledge exploit/explore dynamics as the theoretical framework for this study (H. Chesbrough, 2003; March, 1991; Miller et al., 2006). In this discussion of the combined theoretical framework, we will first thoroughly and individually describe both Chesbrough’s OI and Miller’s extended explore/exploit frameworks and the central tenets of each. Then we will address OI (E²D), the combined framework, and speak to the application of it to this study. Summative conclusions will complete this section.
**Chesbrough’s open innovation (OI) framework.** Chesbrough’s seminal definition of open innovation is expressed as “the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation” (Chesbrough, Vanhaverbeke, & West, 2006, p. 1). Twenty-first century expansion and acceleration of exploitable, explorable knowledge across closed organizational borders and elite research and development groups is proving to be the lifeblood of a new technical knowledge economy (H. Chesbrough, 2015; H. Chesbrough & Brunswicker, 2014; Miller et al., 2006).

From the initial speculative introduction in 2003 until only 11 years later in 2014, an analytical survey of 125 large firms across Europe and the US shows that OI is widely and successfully practiced (H. Chesbrough, 2003; H. Chesbrough & Brunswicker, 2014). A brief, but situating discussion of Chesbrough as a scholar/practitioner is offered in Appendix A (H. Chesbrough, 2015).

Chesbrough’s Open Innovation (OI) conveys a critical change in technical invention mindsets of the 21st century; a shift from isolated, elitist, think tank perspectives to market driven and socially relevant technical innovation drawn from all available internal and external resources. The predominant visual metaphor for OI explains its widespread adoption and active current practice across technology firms – a permeable, funneled flow of ideas (H. Chesbrough & Brunswicker, 2014).

Figure 1.1 shows Chesbrough’s permeable funnel as fully open and enabled technological innovation; an inherently hopeful and futurist message. It also offers a means of understanding an organization’s capacity for OI in the practice of technical innovation; internal and external technology contributions across a broad and diverse base of knowledge as inputs and outputs.
Central to the OI framework are the ideas of cumulative and organic invention and development that flow across boundaries either within or outside of a given organization. This purposive, organic flow must exist in alignment with the practicing organization’s business model. Thus, practicing organizations are predisposed to alliance and partnership through innovation and invention that builds on ideas exchanged in relevant social contexts.

Implicit in the model is the tenet that no business organization can rely completely on their own research. This tenet is founded in the practical realities of the competitive 21st-century high-technology industry (H. Chesbrough, 2012, 2015; Henry Chesbrough & Crowther, 2006). Distributed knowledge must flow to and from opportunity and within and between businesses.

The OI model expresses two distinct and dynamic innovation flows in the form of inside/out and outside/in as extension of these core tenets (H. Chesbrough, 2012). Inside/out requires that organizations share the underutilized technology ideas, concepts, and constructs

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**Figure 1.1.** The combined OI (E2D) framework.
beyond firm boundaries, to mutual benefit (pp. 21-23). Inside/out emphasizes licensing of products, ideas, and more over patenting, which increases openness, transference, and transparency of cultivated exploitable technical knowledge (H. Chesbrough, 2012; March, 1991; March & Sutton, 1997).

Outside/in is the predominant OI practice to date, requiring intake of new knowledge and insight from outside, open sources including existing and emerging markets. This aspect of the framework evidences agile and adaptive invention and development as scalable and fully inclusive through reliance on relevant, informed and highly reflexive technology development (H. Chesbrough, 2003, 2012; Drucker, 1993). The permeability of the funnel enables new and emergent innovation phenomena to be recognized as needed.

The practical exchange of in source technologies may range from contracted consulting to partnering to mergers and acquisitions. Successfully implemented OI emphasizes mutual benefit over opportunistic, imbalanced, one-sided exchange. Thus, the OI model itself depends on open and inclusive exchange of knowledge towards relevant and meaningful value.

The absence or malformed flow of information, the existence of silos and isolated pods of invention allow the model to also function as a spyglass into inefficient, under performing knowledge flow. It is possible to measure the competitive health of a practicing organization based on the degree of alignment to the two defined OI workflows. There remains an inherent dynamic tension between these two primary flows of knowledge.

The core OI model accommodates, but fails to adequately address knowledge as an exploration/exploitation dynamic (March, 1991; Miller et al., 2006). The basic connective hooks within the OI model are present and the tension of exchange and adoption across boundaries
exists. The tension is driven osmotically by relevance to the next consuming link in the chain. But within that exchange and adoption is a riptide of asset evaluation, ongoing, and central to the engine of responsive technical invention and development.

**Miller’s extended explore/exploit dynamic.** March offers the central tenet that an aware, reflective balance between opportunistic, efficient exploitation and risk taking experimentation as exploration is critical to organizational survival and profitability (March, 1991). Where March instructs on the importance of balance between exploration and exploitation of knowledge as organizational survival, Miller et al. work to integrate direct interpersonal learning as “…a decentralized process that takes place without the mediation of an organizational code” (March, 1991; Miller et al., 2006). Miller’s relationship to March’s seminal work is summarized in Figure 1.2.

![Figure 1.2. March’s generational and ongoing influences.](image-url)
Miller et al. invoked Nonaka and Takeuchi to successfully defend the extension of March’s seminal model to explain the rich, chaotic interpersonal dimension of knowledge exploration and exploitation (March, 1991; Miller et al., 2006; Nonaka & Takeuchi, 1995). As a result, a capacity for social evaluation of phenomena beyond explicit and codified knowledge is brought into being. That tacit capacity in March’s model becomes an explicit tenet through Miller et al.’s efforts to extend and deepen the explore/exploit dynamic.

Miller et al. correctly perceived that March’s original model assumes all organizational knowledge as being both explicit and codified (Miller et al., 2006). By introducing the capacity for decentralized, random and unstructured interpersonal learning, the explore/exploit dynamic may now elastically span from organizations and groups to individuals to accommodate emergent innovation models (March, 1991; Miller et al., 2006, p. 711). Thus, Miller et al. successfully extend and amplify the core tenets of March’s explore/exploit dynamic.

Miller et al. invoke a common high-tech engineering term “best practices” when differentiating between codified knowledge as manifestation and tacit, interpersonally shared knowledge as decentralized and highly informal direct “interpersonal learning” processes (Miller et al., 2006, pp. 712–713). Networks of individuals, how they interact, what they do and don’t share therefore have direct relevance and impact on the agility, profitability, and success or failure of high-technology invention (p. 711). This is represented in figure 1.1 by the network icon as a critical intake point.

**Connecting Chesbrough and Miller to form the OI (E^2D) framework.** Chesbrough’s outside/inside knowledge flows are a manifestation of Miller’s extended explore/exploit dynamic at an organizational level. Miller’s framework distills the open, permeable, and relevancy-centric intellectual property management of Chesbrough’s (OI). Thus, it is necessary, possible, and
plausible to construct and apply a conceptual framework that provides the intersection of Chesbrough’s OI and Miller’s extended knowledge explore/exploit dynamic (H. Chesbrough, 2003, 2015; H. Chesbrough & Brunswicker, 2014; March, 1991; Miller et al., 2006).

Technical knowledge’s cultivation and curation is a critical component of the 21st century social and economic fabric. Neither OI nor Miller’s framework alone can fully satisfy that broad context. Both are elastic frameworks with complementary orientations and tenets. Because of OI’s inherent capacity to accommodate an infinite variety of existing and emerging knowledge cultivation and curation practices, Miller’s explore/exploit extension nestles as a key, detailed, interpersonal node. Figure 1.1 reflects that assembled framework, where innovation as profitable social relevance compresses, consolidates, and accelerates.

The emergence of reflexively relevant technology development in major technology corporations encourages the need to clearly intersect OI and the extended explore/exploit dynamic. Implicit in Chesbrough’s framework is a hypertension of exploration and exploitation of cultivated and curated technical knowledge between individuals, within groups and organizations and across permeable organizational boundaries. The explicit point of intersection on relevant, informed development yields a blended, composite conceptual framework of OI and Miller’s Explore/Exploit dynamic: OI (E²D).

The key to linking inclusive and effective innovation to 21st-century technological development is to redefine competitive advantage as the ability to source and contribute with agility, not possess and withhold new and curated technical knowledge (Chesbrough, 2012, p. 25). Thus, OI (E²D) is advocacy for monetized, relevant technological response as a tool for significant social enablement and empowerment through the exchange of knowledge.
That advocacy in the framework would be weakened without the explanatory power of human interpersonal exchange. “Implicit in March’s (1991) model was the assumption that all dimensions of knowledge were amenable to codification; that is, all facets of knowledge could be captured and transmitted from one person to another via an organizational code. “ (Miller et al., 2006, p. 712). Thus, we can reasonably infer an interconnection between interpersonal and organizational knowledge creation and curation in high-technology invention scenarios.

The 21st century’s compression of this core principle of competitive survival as collaborative cooperation is significant. The shift in business practices from knowledge as power (Scientia est potentia) towards knowledge as commerce unto itself (Scientia est commercium) reveals a critical transformation in our economy through technology (Drucker, 1993). This concept is central to both the framework and to understanding the drive for and practice of financially successful technological development.

OI (E²D) enables a comprehensive lens for viewing emergent phenomena that inhibit or enable successful technical innovation practices in scope and context. As these phenomena evidence and present themselves, they may be able to be aligned as predictive indicators of competitive advantage in the 21st century. This may in turn build confidence to embrace more diverse, open business strategies that are fully relevant to market and society in general (Denrell & March, 2001; March, 2006). OI (E²D) grounds and explains the practice of technical innovation as commerce while enabling hope for a socially just, technologically enabled, fully participative world.

**Application of OI (E²D) to the study.** OI (E²D)’s focus on revenue as evidence of orientation to social relevance aligns it perfectly to research question, context, and site. It
provides a comprehensive lens with which to view research subjects’ authentically lived practice of technology invention and development. By seeking to understand the experiences of high-technology engineers’ innovation practices in terms of the 21st century knowledge economy, a comprehensive and authentic range of innovation phenomena may emerge. This study’s lens must show the full range of context, artifact, and more while preserving the authenticity of the narrative shared.

An underlying assumption for this research project is that successful business models are more likely to be adopted because of a common focus on profitability. Competitively successful technological innovation demands full and inclusive participation across diverse perspectives of individuals and organizations. Thus, OI (E2D) carries an implicit message of diversity as simply good, competitive business sense through breadth and depth of varied experience and perspective. The framework reflects how high technology needs to do business (H. Chesbrough, 2015; H. Chesbrough & Brunswicker, 2014).

For the scope, context and intention of this study, business viability and relevant scale is essential to aligning reflexive and relevant innovation with profitable technology invention and development. The selected lens enables analysis and comprehension of all qualitative layers in scope towards recognizing what may be of interest in the data, while providing the flexibility to process the delightfully unexpected. Application of OI (E2D) to this study may help to open doors into new ways of thinking about technological invention and what it may enable.

**Theoretical framework conclusions.** The OI (E2D) framework intersects both Chesbrough’s primary OI model and Miller’s extended explore/exploit dynamic (H. Chesbrough, 2003, 2012, March, 1991, 1996; Miller et al., 2006). This theoretical framework
profiles early 21st century technological knowledge creation, curation, and exchange. OI (E³D) provides a substantive, rich, and well-aligned lens for exploration of this writer’s research question for both organizational and interpersonal learning contexts.

Summary

In summary, the purpose of this research centers on exploring and understanding how engineers describe their own experiences in the practice of agile, profitable, and relevant high-technology innovation. The practical application of technological invention and development towards productive commerce ensures that we are grounded in identified and relevant market need. Only by understanding the phenomena of successful technical invention and development may we presume to attempt to isolate the organic machineries that make it up.

This chapter began with a statement of the problem examined in depth, addressed significance of the research, and discussed the theoretical framework and its explanatory power in context. The next chapter will dive into a comprehensive critique of scholarly dialogue and literature towards reifying choice of theoretical framework and approach to this research.
CHAPTER 2: LITERATURE REVIEW

In this chapter, we examine the scholarly literature on technical innovation mechanics and contexts in this young century, the perceived value of socially developed technological knowledge towards advocacy for the study. We will begin with a review of social innovation mechanics since the central idea in this literature review is the social dynamics for technical innovation in our knowledge economy. The combination and collision of social, cultural, and organizational factors in application show and demand essential dimensions of understanding. This discovery informs on the explanatory power of the chosen framework and the relevance of this study to this body of knowledge.

We will then turn our attention to work contexts as social construct that both defines and is defined by present innovation practice and future visions. The composition of innovation work teams and the cultures that permeate, construct, and deconstruct them invite investigation.

We will conclude the review by examining discoveries and deficits in understanding. A necessary direction in scholarly thought and investigation will emerge. Our collective futures rest on the foundations that we set down in technological practice, in our way of thinking about the future and the technology that either enables or limits it.

We will observe that the literature draws us towards this study’s research focus. These technological innovation practice themes allow us to delve into the essential elements of relevant and authentically practiced 21st century technical invention and development. Advocacy for the study is made explicit by deficits in investigation, understanding, and appreciation of the anatomy of authentically practiced technological innovation.
There is a real danger of jumping to faulty, incomplete conclusions without an inclusive understanding of the full depth and breadth of the literature (Machi & McEvoy, 2009). For this literature review, we will follow the literature and let it speak. We cannot responsibly do otherwise.

**Social Innovation Mechanics**

In this section we will address social dynamics and mechanics of technological innovation. We will work to discover the social and anthropological collectives that make and are in turn made by technical artifacts. We’ll explore the evolution of March’s seminal theory through application across generations of thought.

**Innovation through social processes.** The literature addressing social mechanisms that produce innovation does so through case studies, inference, and analysis. The research reflects multiple academic disciplines, perspectives, and positionality across technology industries. Exploration and identification of the social mechanics and factors that influence innovation spans social cognition theory, organizational dynamics, perceived value as a driver for innovation, social diversity’s influence on collaboration, and more (Paletz & Schunn, 2010; Rindova & Petkova, 2007; Shi et al., 2011).

Previous research put forward a social validation hypothesis which predicted that social role assignment increases information pooling and retention (Stasser, Vaughan, & Steward, 2000). This socialized accountability can be explicit or implicit and appears to encourage voluntary pooling of information across individuals as tested by sampling bias across three person groups (Stasser et al., 2000, p. 112). The researchers hypothesized that a perceived responsibility towards problem solving encourages dialog around information and ideas.
Stasser et al. maintained that collaboration can result from a perception by group members for shared responsibility in context of *expert-role assignment* that prolongs both discussion and examination of shared information (Stasser et al., 2000, p. 104). The distinction between coordination and collaboration is that collaboration informs, but does not restrict information.

Collaboration increases the amount of time and opportunity for exchange of information when there is some degree of *structured exchange*. Stasser et al. identified a substantial increase @22 % +/- in information exchange when there is a structure in place to do so (Stasser et al., 2000). It improves the chances that information is shared across different views, and that open information is shared more completely.

This previous research on the impacts of hidden information and role-assignment’s effect upon it addressed a simple share/unshared social innovation mechanism (SIM) that contrasts strongly to Nonaka’s socialization, externalization, combination, and internalization (SECI) model (Nonaka & Konno, 1998; Stasser et al., 2000). Unshared information differentiates as *Ba*, a commonly accessible space that transcends role and enables a shift from hidden, tacit information to explicit, codified knowledge (Nonaka, Von Krogh, & Voelpel, 2006).

Where Stasser et al. focused on tricking the revelation of unshared information to reveal the *superior option*, Nonaka differentiates as championing knowledge cultivation and creation as essential to SIM (Nonaka, 1994; Nonaka & Konno, 1998; Stasser et al., 2000). It supports the research focus of this study. Thus, the pursuit is of knowledge cultivation rather than just its by-products.
The polar extremes between Stasser et al.’s role-assignment and SECI modes underscores crucial impact and relevance to this study. Tacitly held, implicit knowledge appears pivotal to the development and open exchange of innovative knowledge. This in turn shows that innovation can be thwarted when a specific outcome or solution is desired and enabled by expectations of role and perceptions of expertise in others (Stasser et al., 2000). Therefore, perceived self-expertise is not as beneficial as cultivating trust in exchanging knowledge with others to help initiate, form, and develop creative solutions. This is an intrinsic tenet of the OI framework (H. Chesbrough, 2003, 2015).

DiMatteo et al.’s independent firm productivity analysis substantiated a correlation between social network depth and promotion and diffusion of innovation (DiMatteo, Aste, & Gallegati, 2005). The researchers asserted that the better the social connectivity between firms, the more certain the expectation that innovation as knowledge asset is exchanged and/or imitated. Innovative knowledge exchange as usual is perceived as an efficient route to a specific competitive outcome by these researchers (DiMatteo et al., 2005).

This is interesting in that productivity was measured as proportionate value added to total revenue against number of firm employees. For DiMatteo et al. ideas of value, productivity, and innovation are all measured in terms of capital, not social capital (DiMatteo et al., 2005, p. 2). The choice of language is quite clear and the vocabulary of innovation is one-dimensional. This deficit encourages speculation on what the full, functional anatomy of technological innovation might be.

DiMatteo et al. used existing longitudinal data on firms to extrapolate a random probability distribution model for innovation flow through a social system (DiMatteo et al.,
2005, p. 4). The math is a plausible but bloodless argument for innovation flow in proportion to the depth, variety, and consistent strength of social connections outside of any one given organization. It supports and advocates a reasonably Darwinian framework for the introduction and adoption of technological change (p. 10). The integrity of the model did not address the dimension of social heterogeneity in that it assumed the social network is comprised of a pattern of consistent contact and background. Thus, it is not meaningfully diverse, open, and inclusive and therefore cannot realize full competitive asset recruitment to strategy (Denrell & March, 2001; March, 1991; March & Sutton, 1997).

Laciana et al. dissected marketing campaigns to better understand drivers behind diffusion and adoption of technological innovation as impact to global economics (Laciana, Rovere, & Podesta, 2013). Unlike DiMatteo et al.’s efforts, there is a committed acknowledgement that social networks in innovation are seldom homogeneous or tightly connected (DiMatteo et al., 2005; Laciana et al., 2013, p. 1874). As part of a strong argument for simulation modelling as an exploration tool for innovation diffusion and adoption beyond population sameness, Laciana et al. manipulated micro and macro elements as predictors of marketable technical innovation (Laciana et al., 2013).

While the researchers never clearly defined micro elements to an exhaustive depth, they did leverage the Bass model (macro) which pivots on classifying adopters as either innovators or imitators (Laciana et al., 2013, p. 1876). All so-termed micro elements describe the market topology of an innovation social network in context of the number of innovators, how they are clustered around similar ideas, and how their social distance influences the diffusion of innovation across that network. Thus, the analysis is applicable as innovation contribution into the market-driven framework of OI (H. Chesbrough & Brunswicker, 2014; Laciana et al., 2013).
There is no clear control of technical elitism bias within this past study or adequate definition of exactly what is meant by social distance (Laciana et al., 2013; Saper, 2012). The research scope constrained itself to patterns of market adoption. Scope appeared geared to identify adoption drivers and inform technology product marketing campaigns. Here we see how the researcher touched on technology innovation as exploitable asset through application of tactical manipulation of target markets (Laciana et al., 2013, p. 1883; March & Sutton, 1997).

Other researchers offered the conclusion that diverse social connections across social networking groups may improve competitive collaboration but are difficult to sustain at scalable volume, which is precisely antithetical to proven core tenets of Chesbrough’s OI (H. Chesbrough & Brunswicker, 2014; Shi et al., 2011). Drawing on the wealth of online data from Facebook (@http://www.facebook.com) to LinkedIn (@http://www.linkedin.com), diversity was inferred statistically without making claims on social status or individual racial or ethnic diversity contexts (Shi et al., 2011, p. 4628). Diversity within a network became constrained to differences in research areas such that global diversity was more shallow in contrast than localized diversity was, indicating a greater distinction among closely associated innovators. Shi et al. interpreted this as a decrease in maintained diversity at scale of volume across relationships, as shown in Figure 2.1 (Shi et al., 2011).
The high cost of maintaining diverse relationships in a social network

The synthesis of this socially integrated and created knowledge as innovation into substantial intellectual capital can apparently be described (Kong, 2010). Kong’s Intellectual Capital (IC) framework suggested that members of social enterprises pool their collective knowledge about externally identified needs (p. 164). These needs are then focused around new products and services. The needs are sourced from specific stakeholders and remain the focus anchoring the relevance of the solution scope. Kong perceived a dynamic and complex set of transactional information exchanges as a social mechanism which resonates as a component of SCOT as negotiated meaning (Berger & Luckmann, 1966; Bijker et al., 1987; Kong, 2010).

The defense for this synthesis was wisely rooted in seminal organizational learning theorists (Kong, 2010; Nonaka & Takeuchi, 1995). A cornerstone of that defense is the explicit idea that knowledge through the focused practice of innovation is the only means for strategic competitive advantage (Kong, 2010, p. 162). While it was not an explicit source for Kong’s research, this idea is aligned with March’s explore/exploit dynamic and Crossan’s application of same as a mechanism of strategic renewal (Crossan & Berdrow, 2003; March, 1991).
It would appear that social innovation process mechanisms within this IC framework transfer and transform knowledge (Kong, 2010, p. 167). As knowledge flows across permeable social membranes between those who need and those who know, shared knowledge catalyzes competitive advantage and more, aligning solidly with OI (Kong, 2010; West, Salter, Vanhaverbeke, & Chesbrough, 2014). This dynamic and circular intake and output of shared information is catalyzed by need towards becoming strategic assets.

For this IC framework, the intersection of human, relational, and organization structure reconciles commercial objectives and a greater social mission. This social sharing of information at the crossroads of opportunity and need bring together knowledge and social purpose (Kong, 2010; March, 1991; March & Sutton, 1997). The innovation process in a social context has the capability to integrate knowledge into relevant and strategic assets.

Kong posited that innovation as asset is capital that changes in state during transformation. Innovation capital carries with it information about the organization and social context that formed it (Kong, 2010, p. 168). This relational capital persist the social context of shared and integrated knowledge beyond the borders of the group that produced it. The social context is itself a structural capital essential to the formation and curation of shared knowledge.

Within a social enterprise, knowledge is not just an asset to be controlled and withheld, knowledge is the flow of business commerce. Knowledge is power realized as capital (p. 171). The 21st century exists in a knowledge-based economy, and Kong’s IC framework describes social innovation mechanics that enable both social and strategic benefits. It is a new construct that describes non-profit and for-profit social enterprise innovation. Thus, it clearly describes
social innovation mechanics as a process across diverse perspectives in today’s world (Kong, 2010).

Perceived innovation value can be considered a direct result of cognitive and emotional effects (Rindova & Petkova, 2007). This evidences as a distinctly social context. These researchers stipulated that innovation novelty amplifies perceived value of an innovation event (Rindova & Petkova, 2007). This assertion underscores the impact of socially inferred value in innovation and is a recurrent theme in the literature explored thus far.

A correlation between social cognitive pathways for divergent thinking in diverse groups attempted to map process paths to an abundance of relevant outcomes (Paletz & Schunn, 2010). By mapping both productive and disruptive paths of social and individual cognition, Paletz and Schunn directly linked diversity to optimized originality. Speaking in terms of knowledge diversity and paths to convergence and divergence, the research attempted to address both positive and negative social context effects on innovation.

For Paletz and Schunn, the research focus was to harness the power of multidisciplinary teams for innovation (Paletz & Schunn, 2010, p. 73). By moving the impact and context of convergent (positive) and divergent (negative) past a one dimensional definition, possibilities for granular control emerge. Knowledge diversity, sufficient participation, and information sharing remain core to the equation that enables innovation as a social mechanism (p. 81).

Paletz and Schunn’s efforts at scaffolding their own research enables valid research opportunities in innovation today (Paletz & Schunn, 2010, p. 89). Remarkably, their study described this study’s intended research context. “A program of research might include, first, an
analysis of multidisciplinary and non-multidisciplinary science/engineering groups in the process of team innovation.” (p. 89).

**Findings on innovation through social processes.** The literature shows that social context, cognition and perceptions of value are a dynamic mechanism amplifying and increasing the frequency and quality of shared knowledge for fiscal opportunity and common profit primarily. While innovation novelty can cause adoption to surge, it is the integrative capacity of individual groups that transforms implicitly held knowledge and insight into explicit and strategic competitive assets. Inclusive sharing of information from diverse perspectives towards creation of knowledge as social and organizational asset is therefore essential to meaningful and relevant innovation in an early 21st century knowledge economy.

**SCOT in the early 21st century.** Where the literature addressing innovation through social processes describes driving contexts of relevance, diversity, and more, the literature on SCOT uses technological artifacts as a means to infer group cohesiveness, negotiated influence, and sense making of technology (Bijker et al., 1987; Flanagin, Flanagin, & Flanagin, 2010; Fulk, 1993; Orlikowski & Gash, 1994). The essential advocacy of SCOT is that artifacts historically reflect the social contexts that shape them. This offers a means to process technological creation and development in context of artifacts of environment, work group culture and more (Bijker et al., 1987).

While many regard Bijker et al. as SCOT pioneers, they appear more popularizers than pioneers (Bijker et al., 1987). A prior impassioned narrative on the impacts to social contexts of abandoned and alternate technologies opened a vista into the social construction of technology (Noble, 1984). Noble’s case study showed the quest for a human being-less factory as part of a
greater theme of controlling technology. That resonates as a more compelling question aligned with today’s social constructivist contexts; where and what will our fascination for technology bring us as we construct it and are in turn constructed by it (Flanagin et al., 2010; Noble, 1984)?

It is possible to build on social constructivism and shared incongruent “social realities” aligning on technical artifacts as Technological Frames of Reference (TFR) (Orlikowski & Gash, 1994, pp 174,182). The researchers’ qualitative field study used unstructured interviews across groups within a technology firm defined for influence towards treatment of technology based on TFR. Bypassing the central SCOT framework, the researchers imposed the idea that congruence of shared meaning of technology was both influential and highly individualized, underscoring the impact of diverse, inclusive perspectives in innovation and development participants.

Prior work drew on the SCOT foundation to hypothesize that workgroup technology attitudes stem from the manifestation of individual perspectives as group cohesiveness (Bijker et al., 1987; Fulk, 1993). By extending SCOT to connect social construction as a means to predict workgroup adoption of a technological project, Fulk introduced organizational context as a possible mediating factor in technical knowledge curation and cultivation (Fulk, 1993, p. 945; Miller et al., 2006). Organization as situating context is a foundational assumption in this study as supported by the literature.

More recently, SCOT exhibits as a Social Construction Continuum (SCC) enabled by monetization of software and hardware constructs in a competitive, negotiated context (H. Chesbrough, 2003, 2012; Gustafsson & Autio, 2011). We live in a world where the stock markets may open and close, but the abstracted construct of Market both drives and is driven by the social dialog of a 21st century knowledge economy through “heterogeneous actors” (Fulk,
1993, p. 923). This multidirectional exchange results in networked, negotiated, evolving exchanges that are highly symbolic and reflect a social stock of knowledge.

A more recent study drew on SCOT to situate a “technical code analysis of the Internet” as a simultaneous expression of social construction and social possibility (Flanagin et al., 2010, p. 182). By acknowledging the diffusion of central design authority across the Internet, the researchers were able to examine for shared values, assumptions, and more. The Internet itself evidences as a socio-technical self-evolving construct that responds to inputs and internally generated new knowledge, reflecting the markets and the engineers that continuously invent it (H. Chesbrough, 2015; Henry Chesbrough & Van Alstyne, 2015; Flanagin et al., 2010). Flanagin et al. described the ecology of OI (E²D) without intending to do so.

The researchers asserted that “It is well understood the technical design and social values are interrelated” (Flanagin et al., 2010, p. 180). In doing so, they reinvigorated SCOT’s foundational tenet that technology reflects interconnected social context as negotiated, shared meaning (Bijker et al., 1987; Flanagin et al., 2010). Thus, across individuals, organizations, and groups we see that social contexts are a critical part of understanding the phenomena of technical invention and development.

Previous research performed co-citation analysis across the literature to infer strong relationships for technology cultivation residence and relevance (Di Stefano, Gambardella, & Verona, 2012). Invoking Chesbrough’s OI as both supporting reference and exhibit, Di Stefano et al. called for frameworks and research that expressly establish a better understanding of technological innovation and demand factors as value creation and capture (H. Chesbrough, 2003, 2012; Di Stefano et al., 2012).
“While science and technology provide the trajectories of innovation, demand is a crucial component in order to direct the trajectory towards the right economic venues” (Di Stefano et al., 2012, p. 1291). This reinforces the central relevance of the OI framework to technological innovation in the early 21st century as the only framework to elastically reconcile demand pull and technological push. “Resources, competences, and knowledge can themselves be a source of innovation. This means that in some cases the competences serve the need of simply importing external sources… “ (H Chesbrough et al., 2006; H Chesbrough, 2012; Di Stefano et al., 2012, p. 1292).

Interestingly, the researchers profiled March’s exploit/explore dynamic without acknowledging it as such. “… This cluster emphasizes technology as the main source of opportunities and is influenced by the resource-based and knowledge-based views in stressing the role that firm specific inputs have exploiting these opportunities.” (Di Stefano et al., 2012, p. 1292). Thus, a bibliometric review centered on co-citation may elicit patterns while not capturing an appreciation of the inferences for framework.

**Findings on SCOT in the early 21st century.** The literature provides correlative evidence that technology itself is socially constructed and that the phenomena of effective invention and development of it hinges as much on social contexts and artifacts as it does on the alchemy and mechanics of knowledge creation and cultivation. It reflects the increasing importance of advanced technological invention and development within groups, organizations, and more. Clear patterns and points of intersection with OI (E^2D) are evident as both explicit and implicit references.
**Evolution of March’s dynamic.** March posits that an aware, reflective balance between opportunistic, efficient exploitation and risk taking experimentation as exploration is critical to organizational survival and profitability (March, 1991). March instructs that competitive primacy is a matter of relative efficiency in acquiring knowledge beyond mere tactical advantage (p. 81). Factoring statistically for dimensions of organizational performance, March argues towards informed and balanced employment of risk-taking exploration and exploitative refinement of existing competencies. Simply put, for March, organized and well employed knowledge is organizational survival and is therefore prescient in insights for the 21st century (Denrell & March, 2001; Levinthal & March, 1993; March, 1991, 1996, 2006; March & Sutton, 1997; Miller et al., 2006).

March offers so much even today to both explain and predict organizational learning towards firm performance that it is easy to see how much has been accomplished with it in the greater scholarly dialog across the decades (March, 1991). The key point of instruction is that competitive primacy stems from effective knowledge cultivation and curation beyond short-sightedness and opportunism (March, 1991, p. 81). For March, effectively organized and applied knowledge is everything to a firm’s survival through reflective adaptation (Denrell & March, 2001; Levinthal & March, 1993; March, 1991; March & Sutton, 1997; Miller et al., 2006).

Notice the use of the present term, as March’s (1991) core framework continues to be relevant and vibrant since adaptive organizational learning never stops being directly relevant to any organization’s success. If anything, that need is more compressed as competition and value distinction increases. That does not stop scholars and researchers from adapting and applying March’s core tenets, some more successfully than others.
Describing Crossan’s efforts as mere adaptation to the Marchian dynamic is a disservice to that scholar. Significant dynamic tension between concurrent knowledge exploitation and exploration as a means of strategic organizational renewal remains resonant, if outside this study’s focus (Crossan, Lane, & White, 1999). Perceiving knowledge cultivation as a conversion through intuiting, interpreting, integrating, and institutionalizing (4I), Crossan introduced a multidimensional and multidirectional organizational context, deepening March’s dynamic as transformation of the organization (Crossan et al., 1999, p. 532).

This 4I model as framework demonstrates high elasticity in application and resilience in the tightly coupled feedback loops of 21st century knowledge dynamics (Crossan, Maurer, & White, 2011). Good theoretical foundations enable an extensible framework. The fact remains that an impressive extension still does not accurately reflect the modern hypertension of balance and movement towards exploitable exploration in high-technology (Crossan & Berdrow, 2003; Crossan et al., 1999, 2011).

Where March instructs on the importance of balance between exploration and exploitation as organizational survival, it is possible to observe strategic competition for resource that forces balance into dynamic tension towards organizational growth and change (Crossan & Berdrow, 2003; Crossan et al., 1999; March, 1991). This is tangential to, but not in competition with Miller et al.’s work to integrate direct interpersonal learning as “…a decentralized process that takes place without the mediation of an organizational code” (Crossan & Berdrow, 2003; Miller et al., 2006, p. 710).

Miller et al. made no apologies for extending March’s seminal work. The researchers incisively dissected the original model put forward in 1991 to surgically invoke critical elements of Nonaka & Takeuchi’s insights on knowledge creation (Miller et al., 2006; Nonaka & Takeuchi,
1995). Given the special emphasis awarded to the idea of “multilevel empirical research”, Miller et al. substantiate that March’s dynamic can be credibly combined with interpersonal learning and communication patterns to better understand multilevel organizational learning (Miller et al., 2006, p. 720). This further proves the elasticity of March’s dynamic while injecting a vital interpersonal learning dimension into the original model. This interpersonal dimension is key to the OI (E²D) framework.

Miller et al. correctly perceived that March’s original model assumed that all organizational knowledge is both explicit and codified. By introducing the capacity for decentralized, random and unstructured interpersonal learning, the exploit/explore dynamic may span from organizational to individual and small groups (March, 1991; Miller et al., 2006, p. 711). Canny application of simulation models by the researchers deepened, validated, and enabled credible explanatory power for the model extension for interpersonal, non-codified learning contexts (Bennett, 2016; Miller et al., 2006).

Human and social dynamics may reciprocally drive organizational capital in organizational contexts within March’s Dynamic (Kang & Snell, 2007). The researcher’s advocacy is configuration alignment of human resource as organizational asset towards refinement of competitive value creation (p. 237). Interestingly, Kang & Snell described social contexts, capital, and networks without observing and acknowledging the social constructivist nature pervading their Value Creation Model (VCM) (p. 238).

It is possible to leverage Schein’s influence as “dynamic structural approaches” to extend Kang and Snell’s VCM into an Intellectual Capital Model (ICM) (Kang & Snell, 2007; Winnen & Wilms, 2009, p. 320). Winnen & Wilms’ core argument for the alteration is that knowledge acquisition/sharing as exploration can and must be turned towards efficient exploitation as external
adaptation and internal integration, completely reifying the original central framework. Thus, Kang and Snell’s VCM comes even more closely to March as ICM by way of socially constructed means connecting organizational capital to social capital across organizations in alignment with Chesbrough’s OI (Berger & Luckmann, 1966; H. Chesbrough, 2012; Kang & Snell, 2007; Winnen & Wilms, 2009). Figure 2.2 shows a representation of extended ICM.

Figure 2.2. Representation of the extended Intellectual Capital Model (ICM).

A chi square study distinguished between revealed and deterring barriers to innovation (D’Este, Iammarino, Savona, & von Tunzelmann, 2012). For D’Este et al., revealed barriers represent explicit obstacles to the committed practice of innovation. Deterring barriers constitute blocks and inhibitors preventing organizations from committing to innovation (p. 482). To put this in context of March’s Dynamic, revealed barriers impact both exploitation and exploration.
while deterring barriers stifle an organization’s capacity to create and cultivate new knowledge in either category (D’Este et al., 2012; March, 1991; March & Sutton, 1997; Miller et al., 2006).

Interestingly, examining for a lack of agility in larger firms as deterrence occurred under the assumption that size equates to established markets, “path dependence, and lock in” (D’Este et al., 2012, p. 484). Under this view, new firms are correspondingly deterred by greater volumes of competition and a shallower asset depth; the small and hungry are more likely to be starved out by more established organizations. As good and thorough as the researchers were in their attention to invention and development blocks and hurdles, their honesty on limitations underscores the value of and need for this study’s intended research.

Ultimately, D’Este et al. found for knowledge sharing and regulation barriers as a weaker deterring effect (D’Este et al., 2012). Cost and market barriers emerged for these researchers as strongly deterring barriers to innovation, but without substantive differentiation on market barrier types. Thus, this study’s research focuses on profitable technological innovation as a general boundary for the authentic voice of the engineering practitioner.

D’Este et al. asserted that the relationship between barrier assessment and engagement in innovation activity by firms is non-linear (D’Este et al., 2012, p. 488). Both revealed and deterring effects may emerge in context of any innovation phase a given firm is in as invention and development is at the mercy of the market. The more regular and constant the practice of innovation, the better the engineering organization becomes at finding and clearing innovation barriers over time (p. 485). Without explicitly identifying it as such, the researchers pinpointed meta-innovation as an adaptive learning process. It is a glimpse at a greater anatomy of invention and innovation, an anatomy we must map out to master our own collective futures.
D’Este et al.’s assertion on innovation practice correlates with prior explorations of Schumpeterian widening and deepening patterns of innovation, which reflects competitive dominance through the passage of time (Breschi et al., 2000; D’Este et al., 2012). According to Breschi et al., innovation activities in a specific combination indicate emergence of technological dominance, characterized as *technological regimes* (Breschi et al., 2000). Interestingly, cost concern evidenced consistently among larger organizations sensitive to preserving profit margins. As markets for products hit saturation, the only way to improve or maintain profits is to become more cost efficient in bringing the product to the consumer.

Thus, a consistent pattern of *demand-side* or consumer enabled research in the literature shows that perceptions of relevant need inspire short-term tactical innovation which are short range in vision and geared towards making profit, not sweeping change (Priem et al., 2012). Priem et al.’s analysis of macro knowledge management research streams pivoted on this theme of profit. Cutting across innovation, entrepreneurship and strategic knowledge management studies, the researchers drew on Christensen’s disruptive/customer-focus dynamic, which has parallels to March’s foundational exploration/exploitation and Crossan’s amplification of it towards competitive advantage (Christensen, 1997; Crossan & Berdrow, 2003; March, 1991; March & Sutton, 1997; Priem et al., 2012).

The researchers examined this Marchian “Christensen’s innovator’s dilemma” of technology push/pull, where disruptive innovation struggles against the pull of demand, echoic of the OI(E2D) framework central to this study (Priem et al., 2012). Those researchers’ scope of analysis was driven to advocate customer relevance as critical to technology firm success.

Concluding that “consumer heterogeneity can result in competitive advantage” beyond disruptive innovation, the researchers argued substantively for expedient, tactical, exploitative
innovation as market demand enablement (p. 348). The depth of citation, clear trend in research and constant invocation of financial success impacts allowed Priem et al. to assert decisively that “it is critical for firms to analyze and understand demand factors…” as “…consumer focus is key for firms to successfully innovate or to successfully retreat from a competitor’s disruptive innovation.” (Priem et al., 2012, p. 352). N.B. the use of strategic, combative language to describe such measured conflict between organizations; such is the focused power of applied knowledge as commerce.

Priem et al. further examined symbiotic innovation focused on maximum competitive value by fields that are closely aligned, such as biotechnology and pharmaceutical companies. This collaborative innovation across firms and industry categories is somewhat similar to Chesbrough’s OI in that firms that don’t share revenue risk pool knowledge to independent advantage (H. Chesbrough, 2015; Priem et al., 2012). Unlike Chesbrough’s OI, these researchers made no attempt to measure and define dimensions of value and societal impact, emphasizing economic viability and immediate relevance to current customer needs instead (Priem et al., 2012, p. 369).

It’s plausible to inject a Business Intelligence (BI) model targeting value creation driven from March’s explore/exploit dynamic to hypothesize value dimensions across strategy and operations (Fink, Yogev, & Even, 2016; March, 1991). Resonating as more mind map than predictive model, Fink et al. hypothesized that BI teams positively affect infrastructure and thus operational and strategic capabilities (Fink et al., 2016, p. 7).

In an interestingly creative application of covariance SEM, the researchers sampled across 178 IT respondents to uphold their core hypothesis (p. 11). Thus, BI use may predict effective application tactically and strategically, aligning with March’s Dynamic in reflective practice and
application. Fink et al.’s work remains an effective if mechanistic practical application of March’s core organizational learning theory (Fink et al., 2016; Hatch & Cunliffe, 2013; March, 1991).

All of this fertile research, thought, and more across a hypothesis on outside stimulation/leadership priority mediators, Tamayo-Torres et al.’s examination of ambidextrous flexibility, and Wang and Hsu’s inference of a Power Asymmetry (PA) model serve to underscore March’s continued relevance to organizational learning as adaptive survival (Kammerlander, Burger, Fust, & Fueglistaller, 2014; Tamayo-Torres, Gutierrez-Gutierrez, & Ruiz-Moreno, 2014; C. H. Wang & Hsu, 2013).

Table 2.1 underscores March’s significance in OL learning theory where relative citation depth is attributable to core work. Within this matrix, we infer Construct Elasticity subjectively based on range of application and capacity for adaption without altering core tenets. Multidirectional Affect addresses knowledge influence within and across organizations. Reflection/Action Dynamic shows organizational learning intent and focus across the comparative matrix.

Table 2.1 March’s significance and influence in Organizational Learning (OL)
Findings on the evolution of March’s dynamic. In today’s slipstream of social media as socially constructed continuum, access to resonant, relevant knowledge is another context for March’s ecologies of competition (March, 1991; Miller et al., 2006). The popularization of virtualized work groups in high-technology and more extended and evolved the application of March’s Dynamic as a tool for understanding knowledge curation and creation, giving us Miller et al.’s extension.

Consumer enabled demand is consistently reflected as a major theme and driver in the literature. This shows a focus on organizational expedience and tactical commercial advantage over societal benefit. The drive to understand consumer demand trends and disruptive innovation impacts towards more efficiently marketed commercial assets is an extended application of March’s seminal work. Therefore, symbiotic and beneficially open innovation is insufficiently examined in research.

The 21st century knowledge economy pushes beyond considerations of leader influence and organizational ambidexterity towards tacit and explicit exchange of evolving, constructed knowledge and ideas across mediums, organizational boundaries, and more. Thus, an organizationally and interpersonally relevant explore/exploit dynamic as put forth by Miller et al. is crucially relevant to understanding high-tech knowledge cultivation and curation today.

Conclusions on Social Innovation Mechanics

The literature shows that social contexts as perceptions of value dynamically amplify and increase exchange and trade on assets and artifacts of knowledge as business. Technology itself is socially constructed. The phenomena of effective, efficient invention and development evidences as patterns and intersection with the OI (E2D) framework throughout the research.
Social mechanics and construction of technology combine to define both present economics and possible future directions.

Single minded and imbalanced pursuit of profit is shown to inhibit relevant, inclusive invention and development. Symbiotic and inclusive innovation is insufficiently examined in the research, especially in context of the dynamic tension in technical invention and development. This reinforces the crucial relevance of both Chesbrough’s OI and March’s Dynamic in high-tech knowledge creation, cultivation, and curation in the 21st century. OI (E²D) scaffolds this study’s research focus.

The literature also underscores the OI (E²D) framework’s orientation to a vibrant and emergent source of technology in the form of both crowdfunding adoption and inclusive diffusion of high-technology knowledge assets. Language in the research brings forward innovation as spread through social contact. The effective exchange and curation of new technological knowledge is insufficiently explored.

**Context of Innovation at Work**

**Innovation team cultures, contexts, and composition.** Research into innovation workplace cultures and individual employees sought to assert the hypothesis that employees are happier in a positive innovation culture (Wei, O’Neill, Lee, & Zhou, 2013). Drawing on Pettigrew, it is possible to define innovation culture as “a cohesive force that leads individuals to share values, social ideals and beliefs” (Pettigrew, 1979; Wei et al., 2013, p. 1029). The researchers labored to make the case that a truly innovative culture is valuable, rare, and socially grounded on “perceived market information sharing” as identified opportunity (Wei et al., 2013,
p. 1029). Without saying as much, the researchers defined the core of a vibrant knowledge economy; organic, mutually beneficial and geared for competitive cooperation.

The researchers factored this cohesion in terms of job satisfaction and perceptions of Chinese firms’ performance as innovative vitality (Wei et al., 2013, p. 1038). The researchers further connected the benefits of information-sharing across markets persuasively, arguing that knowledge creation for competitive exploitation only is it itself a barrier to dynamic innovation. As echoic of March’s counsel as that assertion remains, the researchers failed to acknowledge seminal thought (March, 1991; March & Sutton, 1997; Wei et al., 2013). They did acknowledge that human resource depth and commitment mediates firm innovative vitality, while failing to acknowledge Crossan’s application of March’s Dynamic as strategic organizational renewal (Crossan & Berdrow, 2003; Wei et al., 2013).

It is plausible that high workloads in context of overall team performance demands can be a significant barrier to financially efficient and effective innovation (Bedwell, Salas, Funke, & Knott, 2014). The researchers defined team workload as “the relationship between the finite performance capacities of a team and the demands placed on the team by its performance environment” (p. 100). Put more simply, team workload is the potential work a team can accomplish less its actual active work assignments.

Bedwell et al.’s synthesis across literature identifies team workload as made up of team, task, and work environment characteristics (Bedwell et al., 2014, p. 101). Workload capacity can be hampered by environmental stressors such as performance expectations. Time constraints, repetitive, unengaging work, and high penalties for mistakes inject stressors into the process of invention and development, reducing effective output and efficiency.
By identifying three categories of work stressors as context, role, and task, the researchers discussed the potential impact of knowledge workers participating in more than one team. Unable to substantiate that element of impact, the researchers instead called for future research on individual employee authentic perspectives on work stressors and performance (Bedwell et al., 2014, p. 119). The call for authentically lived perspective is a vital and valid alignment to this study.

Previous research into the effects of mood and stress on group communication and awareness hypothesized that cognitive focus is narrowed as stress increases, shifting mood toward the negative (Pfaff, 2012). Pfaff achieved this insight by manipulating stress through a timed solution study, mediating communication through computers and measuring mood only as a binary state (happy/sad) (p. 560). Virtualized, indirect communication is assumed to subtract contextual meaning within the medium even today (McLuhan & Gordon, 2003). While not a direct study of engineering practice, authentic contexts and participant voice, it did somewhat simulate the virtualized communication contexts prevalent in high-technology development (Pfaff, 2012).

This particular communicational hurdle within that previous research reflects a real world challenge element for global work teams today. Exchanging ideas and building knowledge within the constraints of currently available technologies appears to increase stress, confusion and impede efficient new knowledge creation and curation (Miller et al., 2006; Pfaff, 2012). This continues to be a valid focus for exploration.

Pfaff asserted quantitatively that while cognition is thought processed within a single mind, social cognition is the interplay of thoughts across separate minds, perspectives, and
positionalities (Berger & Luckmann, 1966; Pfaff, 2012; Schwandt, 2010). The researcher was quick to assert that stress alone can’t be dismissed as a purely general negative distraction to an otherwise consistent flow of information. Stress narrows attention to primary tasks, increasing focus at a cost to attention to peripheral data (Pfaff, 2012, p. 562). This can only impact flexible, lateral thinking and collaborative and inclusive solution generation, which is shown across the literature to be essential to effective invention and development.

Assessing the role and impact of expertise in software design teams explicitly is possible based on prior research (Volmer & Sonnentag, 2011). The researchers pulled from “longitudinal, multi-source data across 96 professional software design engineers” to divide expertise into task and team function categories (p. 219). Volmer and Sonnentag statistically substantiated a positive, predictive relationship between expertise and team performance across software engineering organizations. This implies that intellectual leadership as perceived expertise enables both task and team level success.

Their research asserted that effective seeding of “star” performers raises the level of performance both at the task and team function levels. Skill competency alone does not appear to make for effective solution development as engineering practice. Expertise is a more impactful and broader generalized ability (Volmer & Sonnentag, 2011, p. 230). Volmer and Sonnentag asserted that just like cognitive capacity, individual personality, bias, background, and degree of perceived expertise combine as impacts in technology team dynamics. Thus, understanding engineering participants’ authentic experiences of innovation is underscored as having critical value to work contexts and more.
Past research applying a hybrid Multiple Criteria Decision Making (MCDM) analysis into China’s printed circuit board engineering industry struggled to isolate Technological Innovation Capabilities (TIC) as organizational characteristics (Cheng & Lin, 2012). These researchers attempted the argument that R&D capabilities and effective resource allocation are critical to “sustaining competitiveness of Chinese firms” (p. 291). This further reifies the importance of effective economic competition through best use of engineering resources.

Cheng and Lin derailed their advocacy by acknowledging two severe compromises to research discipline (Cheng & Lin, 2012, p. 312). First, a framework of fuzzy set theory was retroactively applied to the survey research as an afterthought. Second, the researchers stated that “the perception of TICs might be biased because additional effects could exist” (p. 313). As a result, the researchers failed to substantiate and realize a plausible advocacy argument.

**Findings on innovation team cultures, contexts, and composition.** The literature shows that innovation and social work contexts have a complex and fragile relationship, particularly in high technology engineering. Team compositions, communicational contexts, workloads, stressors and unforeseen barriers can thwart or accelerate the creation of innovative solutions which in turn directly impacts organizational competitive survival. Given the correct balance of stimuli and conditions, work environments can focus the innovation process towards relevant, efficient, directed monetizable value. Research explicitly calls for exploration of participants’ perspectives on enablement and inhibiting phenomena in innovation work, aligning strongly with this study.

**Firm as innovation incubator.** Past research investigated essential drivers in competitive innovation in small firms where resources are at a premium (De Jong & Vermeulen,
2006). Through analysis of survey data across 1250 small firms and multiple industries within the Netherlands, the researchers looked for variances in drivers and determinants towards alignment of market requirements and the innovation process (p. 588). Controlling for firm size and maturity, De Jong and Vermeulen found for flexible and adaptive innovation processes within newer, less established firms (De Jong & Vermeulen, 2006).

The researchers proscriptively identified study limitations, excluding innovation adoption and an overemphasis on product-centric innovation, purposefully selecting exploitation of existing assets rather than exploration of visionary advances within a given field (De Jong & Vermeulen, 2006; March, 1991; March & Sutton, 1997). This would imply that smaller firms gain focus and agility due to lack of size and organizational complexity, while the corresponding lack of resources and broadened revenue base hampers market base and resilience. It would seem that exploitation of existing product remains a strong stimulus for narrow but directly relevant innovation where there is clearly identified market opportunity.

A significant reification of OI (E²D) springs from these acknowledged limitations and drivers. The interdependence of firm size, maturity, and innovation process tracks as being influenced strongly by market focus in favor of exploitable innovation. De Jong & Vermeulen called explicitly for a deepening in the understanding of innovation determinants (De Jong & Vermeulen, 2006). The breadth and depth of applicability of OI (E²D) therefore extends across the dimension of firm size as a reflection of the active configuration of a firm as part of a greater innovation ecology.

OI-focused past research investigated market entry and exit as a factor of firm configuration and scope within disk drive engineering firms. (Henry Chesbrough, 2003). Where
larger firms have advantages for survival over time, how a given firm chooses to assemble resources differs across engineering firms (pp. 663-665). Spinoffs of specialized teams into subsidiaries and wholly independent firms allow specialized orientation to sub-markets and more as an economically driven expansion of a firm’s innovation ecosystem. Agility to market appears to want to be less encumbered and more committed, where capital investment is a constant defining impetus.

Advocacy for emergent small firms as cells and creative sources of high-technology innovation is evident throughout the literature. Case studies into disruptive “technology specific advocacy coalitions” addressed a dimension of inclusive innovation past market demographics, focusing on societal need and relevance (Brown, Hendry, & Harbone, 2007). The impact of sustainable energy and radically disruptive high-technology was explored across two young, small engineering firms struggling to disrupt business as usual (p. 604). More often than not, market access in an established field is constrained to established suppliers, which mediates introduction and scope of innovation ecology.

This information profiles less as saturation, and more as a particular type of dominance of an established clientele. The resonant instruction that innovators must “…base their work in this thematic analysis of the sources of innovative opportunity” applies today (Drucker, 1993). Simply put, firms of any size and type seeking to disrupt the competition must do the homework and the market analysis. They must base their strategies in market relevance to succeed, a core tenet of Chesbrough’s OI (H. Chesbrough, 2003, 2015; H. Chesbrough & Brunswicker, 2014).

A prior case study revealed that advocacy coalitions that spring up in the face of significant and disruptive innovation encourage adoption and offset the stranglehold of
hegemony (Brown et al., 2007). The researchers also used the term *technological regime* in their case studies to describe the dominance and hegemony of electrical power in the energy field (Breschi et al., 2000; Brown et al., 2007; Schumpeter, 1942). Thus, disruptive innovation shared inclusively among collaborating firms towards pursuit of profit injects a dimension of both social construction of technology (SCOT) and social relevance, significantly (Bijker et al., 1987; Brown et al., 2007; Levinthal & March, 1993; March, 1991; Tucci et al., 2016).

This prior exploration of technology development through advocacy coalitions leads to a partial map of innovation factors (Brown et al., 2007). The researchers attempted a schematic representation of the dynamics of innovation enablers and inhibitors within their small firm case study, as shown in the Figure 2.3. Company innovation process is at the center of the figure, shaped by and in turn shaping interactions with collaborators, potential markets and more.

Note the clear intersection points circled in red with OI (E²D) identified by Figure 2.3’s mapped factors (Brown et al., 2007; H. Chesbrough, 2003; March, 1991; March & Sutton, 1997; West et al., 2014). It invites speculation on the degree of their association and influence as driving and mediating roles, and what equations of predictive relationship may be inferred and hypothesized. Thus, the literature again informs on the relevance, elasticity, and valid application of OI (E²D).
Prior analysis applied Schumpeter’s lens to link public funding as a stimulus to innovation across firm profiles with interesting implications (Herrera & Sanchez-Gonzalez, 2012; Schumpeter, 1942). Performing summary analysis across case studies, the researchers correlated R&D subsidies to firm size to assert that public funding most consistently benefits small to medium private firms starting up an initial innovation (Herrera & Sanchez-Gonzalez, 2012, p. 148). The implication is that firms created and funded to respond to identified public needs tend to develop highly socially relevant inventions.

Herrera and Sanchez-Gonzalez identified a drop off in innovation alignment to public need over time as dependency on public funding becomes less central to a given firm’s growth. Persuasive advocacy was made for further research to identify innovation spikes so that public policy can fund and focus beneficial innovation in firms of any size (Herrera & Sanchez-Gonzalez, 2012, p. 150). Thus, economic innovation enablement from policy-driven grant award may be an underused stimulus for financially effective, socially relevant innovation. At the very least, it suggests a more complex anatomy of technical innovation than previously identified.
The researchers acknowledged survey limitations in research question focus on grant sources as well as timeframes and study duration. The question of representative government necessarily being fully and meaningfully inclusive remains. “We should not forget that the process involving the distribution of public funding implies, in turn, that public agencies make decisions about what aspects of innovation activity and technological change are to be stimulated to the detriment of others” (Herrera & Sanchez-Gonzalez, 2012, p. 151). Herrera and Sanchez-Gonzalez offered that focus on financial stimulus alone is an inadequate indicator of relevance and inclusion.

**Findings on the firm as innovation incubator.** The literature shows a strong correlation to firm size and adaptability in innovation processes such that smaller, less established firms more fluidly orient to competitive opportunity. Small to medium firms also tend to profile as more responsive to funding stimuli, including public policy grants. Thus, smaller, more agile firms appear to cultivate beneficially disruptive technologies through coalitions, which in turn tend to encourage more diverse, heterogeneous participation in all phases of the innovation process. Financial motivation and focus remains a primary driver of analysis across the literature while points of alignment to and intersection with the OI (E^2D) framework emerge.

**Conclusions on the Context of Innovation at Work**

This thread on the 21st century knowledge economics observes that progressive and financially effective social construction of technology demands open examination of authentically lived social contexts. Research explicitly calls for the exploration of participants’ perspectives on enablement and inhibiting phenomena in high-technology innovation work, aligning strongly with this writer’s research intentions. Literature investigating the interplay of
firm size maturity in invention and development informs on both the relevance and valid application of the OI (E^2D) framework to this writer’s study.

**Literature Review Summary and Conclusion**

The literature demonstrates that it is open exchange and collaborative capacity that transforms implicitly held technical knowledge and insight into explicit and strategic assets. Competitive commercial assets come first to organizations while being socially constructed, negotiated, and revised within and across these boundaries, the organizational membranes of an innovation ecology.

Authentically lived experiences of financially effective, inclusive development of technological knowledge from diverse perspectives is severely under examined across the literature. Investigation into innovation experiences as a participant observer is apparently unique in high technology engineering. This absence of examination and understanding into a pivotal component of the 21st century knowledge economy is a compelling advocacy for the study itself.

When consideration for the human element does appear, it shows up as resource variables helping to plot success in market entry strategies. The literature shows that research into authentically experienced enabling and inhibiting innovation phenomena is severely under researched. It would appear that the 21st century technical knowledge economy ticks along like clockwork, oblivious to the intensely human organic elements caught up in its gears.

Social contexts and negotiated perceptions of invention and innovation value are shown to be a complex, organic, and often parochial social mechanism. Increases and decreases in the frequency and amplification of shared knowledge are roughly plotted without being well and fully understood. The literature shows constrictive focus on competitive advantage and fiscal
profit while remaining blind to the authentic, lived experience of those that practice it. The OI (E$^2$D) framework therefore provides a relevant and aligned comprehensive lens for the compelling research questions addressed in this study.

The early 21st century global knowledge economy is reflected in the literature as a single minded and narrow corporate and parochial pursuit of expedient, exploitative profit within regulatory limits and funding. The literature does not present a collective, profiled knowledge economy nor does it delve into substantive narrative of practical engineering experience. Studying only the results of inventive phenomena is like trying to guess at the speed of the current and the intensity of sunlight that a living Atlantic salmon swam in from the dry, desiccated bones of a salmo salar specimen antiseptically mounted on a board.

Organizational composition, workload, stress and agility in meeting unanticipated hurdles are shown within the literature to both thwart and accelerate technological innovation. Balanced, open, permeable work environments can potentially enable the technological invention and development process towards socially relevant, directed value. Thus, the deficits in research calls for exploration of active practitioner’s authentic perspectives on high-technology innovation work.

**Thesis and summation**

The evidence presented within the literature fully support this writer’s intended research focus. Fully effective technological innovation must be socially relevant, inclusive, and beneficial to attain competitive and financial success. The practice of technological innovation is shown to be much more than the sum of individual elements, mediators, and components. The practice of it is a matter of storied perspective across cultures and individuals; the unique
alignment of such elements and artifacts scaffold the phenomena as it is negotiated and revised into technological constructs.

The literature provides an excellent advocacy argument for this study. There is an explicit call for research on individual employee perspectives on inhibitors and enablers in context of workload (Bedwell et al., 2014). There is an explicit call for exploration and analysis into “multidisciplinary science/engineering groups in the process of team innovation” (Paletz & Schunn, 2010, p. 89). These calls and more compel the line of research investigation and methodology we will examine in the next chapter.

Our collective need to shape our futures compels this study to be performed. The absence of exploration into authentic practitioner experience underscores the pivotal importance of narrative inquiry (NI) as a tool for understanding. In conclusion, the literature inarguably describes gaps in the granular understanding of social context and the fullness of cataloged technical invention phenomena. In the next chapter we will begin to unearth this understanding through focused research methodology.
CHAPTER 3: A QUALITATIVE INQUIRY

This chapter addresses the study’s research purpose, researcher positionality, design, data collection, analysis, trustworthiness and limitations. Describing the application of method to exploration of high-technology engineers’ authentic experiences while they practice agile and profitable innovation is central to the chapter. A qualitative method of investigation will best answer the question of how these engineers describe those experiences in their own voices.

There is strong consensus that qualitative study is arguably the best approach for comprehensive exploration, explanation, and full understanding of complex processes and activities (Andersen & Taylor, 2007; Patton, 1990; Ponterotto, 2005). Thus, qualitative study as a means to explore and understand the described experiential phenomena fulfills all explicit and implicit goals for this study and aligns strongly to its purpose.

Purpose Statement

The purpose of this study is to explore and understand what authentic experiences high-technology engineers encounter while practicing agile and profitable invention and development through their own voices and professional and organizational contexts.

Positionality Statement

I will attempt to frame personal and professional background in context of this research study. Reflective, considered analysis of positionality as impassioned advocate and researcher will reveal bias that could easily undermine, contaminate, and thwart the research effort. Conclusions will be drawn on how best to account for these biases within the research.
**Author background.** I have been a hardware and software engineer for over 30 years and am an acknowledged global champion of technological innovation. Specific attainments include being the father of two new programming languages, holder of multiple patents in software, and best in show 2013 at EMC’s Innovation Roadmap competition, placing 1st out of 4,500 elite engineers worldwide. It is possible to see high-technology as a creative practice, seeing patterns outside of and within the intended uses of individual designs.

That capacity appears to be cultivated through cumulative life experiences enabling one to see problems differently and encourage genuinely adaptive, out of the box thinking. Without really considering it, awareness of the complexity and rich depth beyond the obvious had happened over time. Suffice to say a strong, passionately biased position in favor of integrated science, technology, engineering, arts, and math (STEAM) education for all as a simple human birthright was and is a truth for me (Guyotte, Sochaka, Costantino, Walther, & Kellam, 2014; Reitenbach, 2015). I simply hadn’t that particular label for the idea until recently, most likely because of the necessary reflection of doctoral dissertation.

This present mindset seems heavily influenced by having grown up in a Yale faculty enclave outside of New Haven, Connecticut in a predominantly blue collar Italian-Scots family. Growing up in a vibrant ‘60’s suburban neighborhood is not unusual. What apparently made it unusual was the cultural patchwork of profoundly intelligent neighbors who happened to profess to teach philosophy, science, languages, and literature. It was simply home. I am therefore strongly biased in favor of true social inclusion across cultures, beliefs, and backgrounds (Banks, 2007).
This very informal and unstructured education from an extended neighborhood family of ichthyologists, linguists, professors of philosophy and art encouraged an openness to other perspectives. Diversity wasn’t an abstracted ideal; it was completely natural.

All kids get caught misbehaving. I was no different and was often caught stealing strawberries (*ttalgi* in Korean) from Dr. Chang’s garden a few houses down from my own. Punishment was to serve as a very junior research assistant while *halmeoni* (Korean for grandma) Chang made everyone fresh strawberry ices. There we kids would sit getting lessons in Korean while helping to detail idioms, slang, and more while Dr. Chang pounded out a remarkable Korean to English dictionary on a white underwood typewriter with sticky keys. That dictionary is still in publication today, 50 years later (Martin, Lee, & Chang, 1967).

It was this and many other informal but vital experiences that brought home the belief and bias that being *other* was not a threat, but a gateway to something wonderful because of the differences in thinking observed (Briscoe, 2005). The cumulative effect on positionality and this study is a strong, impassioned belief that it is our differences that bring the most positive, interesting, and stimulating outcomes when we view questions and problems from our individual, authentic perspectives.

This prejudice for new perspective has been strongly reinforced throughout this writer’s decades-long engineering practice. A steady stream of awards, patents, and financial success for thinking well outside of the box and turning problems into assets is as hard to deny as it is addictive. While this thirst for fresh perspective is a good match for engaging in narrative inquiry (NI) of engineers’ experiences, bias remains bias and a threat to truly open research. “A
researcher hobbled by unchecked bias, can only produce biased findings” (Machi & McEvoy, 2009, p. 19).

Where high-tech engineering practice is the pursuit of specific results through applied theory, then truly skeptical and open research can only happen when that mindset is identified, acknowledged and a constant commitment is made to the research data above all. Machi and McEvoy (2009) assert that passionate interest make research possible and that personal opinion must be controlled to avoid the “jump to premature conclusions” (p.19). That same ability to infer complex patterns towards creating a software construct could derail the data and turn good research into irrational assumption. Being biased towards extreme open-mindedness when engaged in NI is deeply ironic and must not become a close-minded validation of researcher positionality.

This challenge is further heightened by being a privileged, insider researcher in an admittedly intellectually elitist industry that prizes cleverness over scholarly rigor (Saper, 2012; Vetter, 2014; Weiss, 2014). I will struggle with being an enlightened and correct practitioner of technology, a member of the Technogentsia, every day if need be. The term Technogentsia describes an informal offshoot group of modern Intelligentsia, who believe that Technology’s purpose is to serve society through the attainment of scientific, cultural, and human understanding. “If you have come to help me, you are wasting your time. But if you have come because your liberation is bound up with mine, then let us work together.” (Sankofa Waters, 2015, p. 29).

Control of bias and personal opinion to produce valid research foundations is fundamental (Machi & McEvoy, 2009). It is a familiar theme across scholarly work and is both a sound and familiar practice. Wrestling with personal positionality and staying open to
unexpected outcomes in order to develop new knowledge is at the core of technical innovation. To proceed from a foregone conclusion is to miss out on unexpected and unanticipated delights and surprises. We are all surrounded by everyday miracles as unique and impermanent as a sweet, succulent and forbidden *ttalgi* in a kind old man’s garden on a bright summer’s day so very long ago.

**Author positionality conclusions.** The data, the authentic voices of the research participants’ engineering experiences must be heard. Being faithful to the perspective, voice, and individual positionality of all research subjects is a responsibility and a privilege. My immersion in the practice, vocabulary, and challenges of high-tech engineering will help to access the authentic data so long as researcher bias is not allowed to undermine it with preconceptions (p. 15). “Phenomena also shift depending on how we frame their contexts and our researcher positions within the contexts.”(Clandinin & Connelly, 2000, p. 126).

**Research Design**

Application of a constructivist paradigm and inquiry flowed logically from this intent to explore and understand the experiences of high-tech engineers. “Reality is intersubjective in that it is socially constructed, such that it can be described and represented through diverse perspectives” (Butin, 2010, p. 59). Pursuit of substantial construction of meaning and interpretation of engineers’ subjective realities were encountered, influenced by prior understanding, artifacts, context, and knowledge (Cobern, 1993; Michie, 2013; Stake, 1995; Yin, 1994). Engineering knowledge is no less a socially constructed body of knowledge, built and maintained by experience.
Where Guba and Lincoln perceive both individuals and groups as constructors of personal realities through perception, Butin sees intersubjective meaning making by means of different and unique perspectives (Butin, 2010; Guba & Lincoln, 1994). NI therefore emerges as a highly effective qualitative method for understanding high-tech engineers’ knowledge and experiences through their authentic voices, contexts, and artifacts.

**Narrative inquiry’s philosophical underpinnings and assumptions.** Within the focus of qualitative study, philosophical nuances color researcher roles and stances, ranging from emphasis on the “how” of meaning making to explicit guidelines geared to “legitimizing” qualitative research (Andersen & Taylor, 2007; Elliott, Fischer, & Rennie, 1999). Qualitative researchers who may differ on research and analysis approaches share a common appreciation that belief influences study design and methodology.

Beliefs as paradigms are philosophical assumptions given framework, scope, and intent (Guba & Lincoln, 1994). Philosophy is tightly intertwined with qualitative research methodology across three principal focal areas. Ontology as nature of reality, epistemology as subjective construction of truth, and axiology as embedded, acknowledged bias are woven into qualitative methodology underscoring its inductive nature of analysis (Creswell, 2013). Ultimately, the validity of subjective interpretation towards constructed understanding of phenomena is central to all corners and applications of qualitative methodology (Creswell, 2012, 2013). This study is no exception to that.

If the intent is an effective and authentic retelling of phenomena, true to the story and fully authentic to the diverse experiences of the research subjects, then a narrative qualitative methodology in context could not help but become strongly compelling (Çelik, 2012; Clandinin,
Murphy, Huber, & Orr, 2009). Narratives are autobiographical as events across time and not isolated incidents or event phenomena per se (Clandinin & Connelly, 2000). The scope is the individual, emphasizing a psychological, individual set of experiences across phenomena (Clandinin & Connelly, 2000; Schwandt, 2010). Thus, narrative inquiry is no less authentic for these characteristics, no less a qualitative expression of constructive interpretivism (Hickson et al., 1993).

Narrative inquiry focuses in on understanding individual past and present meaning, contexts, artifacts and more as authentic experience (Creswell, 2012, 2013). “As we have tried to make clear throughout the book, theoretically, the main issue is for inquirers to sort out a narrative view of experience.” (Clandinin & Connelly, 2000, p. 127). Therefore, qualitative approach as NI must be informed by researchers’ intentions, issue scope, positionality, philosophy, and more as the researcher is in fact the research implement (Maxwell, 2012).

So, we observe a collision between the researcher role in NI as the primary data collector with the need to bracket out acknowledged bias, predispositions, intuitive assumptions and more from impacting, influencing, and degrading the authenticity of the research results (Creswell, 2013; Lincoln & Guba, 1985). It is not a collision that can be avoided just once or even twice in the process of designing and conducting research. It is an unavoidable and central responsibility for any researcher to preserve and protect authenticity of voice, artifact, and context shared through interview and other means by research participants (Creswell, 2012, 2013; Miles, Huberman, & Saldana, 2014).

Deep reflection across analytical methods and approaches is critical to correct design. Factoring for authenticity, trustworthiness, and more in alignment with the scope of this research
demanded reduction towards essence as NI (Dowling, 2007). Further, a study that explores engineers’ work contexts and experiences in technology must begin with, and remain rooted in individual, authentic, lived experience (Baker, 2015; Dowling, 2007).

Therefore NI methodology aligned as ethnographic (Creswell, 2012), as a vehicle for interpretivism (Butin, 2010), and allowed a central connection across the three philosophical axis of qualitative research (Butin, 2010; Creswell, 2012, 2013; J. A. Smith, 2004, p. 11). “Narrative inquiry boundaries expand and contract, and wherever they are at any point in time, they are permeable, not osmotically permeable with things tending to move only one way but interactively permeable.”(Clandinin & Connelly, 2000, p. 115).

In summary, narrative inquiry within a constructivist paradigm was the purposefully selected qualitative methodology. A study that explores authentic experiences in the invention and development of high-technology must begin with, and remain rooted in individual, authentic, lived experience.

**Participants.** The study was piloted with 2 high-tech engineers. Six research subjects were pre-filtered and purposefully selected for the study based on the following criteria:

- Technical competence and experience in technological innovation.
- Above average oral and written communication skills.
- A desire to share their experiences in technological innovation.
- Possession of three to fifteen years of experience working in high-technology engineering.
The hiring criteria imposed by the site implied a degree of pre-filtering and proven professional competency and experience in engineering. Potential subjects ranged from between three and thirty-five years’ experience in the profession, with education ranging from four and five year degree programs to less than 10% doing some form of post-graduate work. We now turn our attention to the research site.

**Site.** Physically headquartered in the north eastern United States, the research site offered opportunities to capture authentic, wide-ranging experience and practice. The base population of 70,000 employees, was made up of @65% engineers. Age ranges, ethnicity, race, and gender were not an intentional boundary to selection. “Qualitative samples tend to be purposive rather than random.” (Miles et al., 2014, p. 31).

The research site’s business focus ranged broadly from the casual home user to other multinational corporations around the globe. The common characteristic among these diverse customers and broad markets was a strong reliance on the infrastructure and services that define the 21st century knowledge economy. The site developed solutions, services and products that remain central to managing the data that drives such an economy. Our attention now turns to the process of soliciting participants.

**Recruitment and access.** Potential candidates were drawn and purposefully selected as described from an open database of invention enthusiasts available at the site. Initial contact for this study came from the recruitment letter shown in Appendix B. Emphasis was made on the importance of protecting confidentiality and anonymity. Prospective volunteers were asked to contact the researcher directly by phone or via e-mail for consideration.
Protection of human subjects. An emphasis was consistently placed on protecting participant confidentiality during initial recruitment and all subsequent communications. The sample interview script found in Appendix C includes written affirmation on participant confidentiality.

Any and all responsible research involving human beings as participants in an academic context requires review and approval by an institutional review board (IRB) (Creswell, 2012; Merriam & Tisdell, 2015; Richards, 2014). This study is no exception to that rule. As it applies to this form of research, the chief intent is participant protection and to ensure a sampling population cannot be exploited or otherwise abused (Richards, 2014; Young, Hooker, & Freeberg, 1990).

Safeguards for participants included but were not limited to a guarantee of participant confidentiality as part of signed consent (Appendix D). All participants were fully informed of this study’s intention and purpose as part of that guarantee of confidentiality. Pseudonyms were used throughout data collection and analysis to protect participant anonymity and guaranteed confidentiality. Sound ethical practice stemmed from courteous respect, appreciation and recognition of the subjects’ vital importance to the research.

Data Collection

Narrative Inquiry recognizes multiple paths and approaches to data collection while asserting that the researcher is the instrument of interpretation (Baker, 2015; Creswell, 2013; Miles et al., 2014; Patton, 1990). As a result, a combination of semi-structured interviews and writing prompts facilitated relevant, context rich data collection (Miles et al., 2014). The interview protocol mapping, pilot interview, and collection procedures used in the study follows.
**Interview protocol.** Solid design in qualitative research demanded attention to alignment between core research focus and the methodical approach to fulfilling them, not unlike a solid technological design (Gamma, Helm, Johnson, & Vlissides, 2015; Stevens, 2000; Yacoub, S.M., Ammar, 2004). In the case of this study, the researcher was the instrument and the overarching research question and its supporting questions remained central throughout. They are summarized in Appendix E. This approach to interview protocol (IP) provided a way to map out and directly relate research question alignment to interview question assignment.

To help encourage full engagement on the part of the participant, the interview design incorporated *high-yield* question structures to engage participants with different methods of thinking about response and context (H. Chesbrough, 2015; Seidman, 2013). By attempting to push past the concept of true and false or open ended questions, high-yield questions encouraged active, invested reflection on the part of the participant. Rich, storied dialogue, intended to take the interview towards what is of interest was the objective of this design (Seidman, 2013). This in turn helped authentic voice and depth of lived experience to reveal itself.

Probes and follow-ups were kept fluid and as alive as possible within those semi-structured categories. Dialogue was kept flexible and responsive to participants’ shared experiences. This was critical to honoring the overarching research question in the study. Organizing both interview questions and writing prompts by participant meaning making category helped to organize the story and rich data it represented (Miles et al., 2014).

By mapping interview questions to the research question, coding became recursive and a primary or first cycle coding allowed inductive learning for the researcher as a heuristic (Miles et al., 2014, p. 73). Simply put, coding proved a means of discovery that demanded deep reflection
and attention to all elements of the data upon intake. We will discuss coding processes in greater detail in context of data collection.

Appendix E details explicit sample interview questions as driven by the study’s research questions; these figures provide a kind of schematic intended to align intention to potential outcome. The focus remained on “words as the basic medium” of the data and the assumption proved valid that the words involved would be refined into clear, well annotated text (p. 71). Having discussed interview protocol as a structured but elastic design, we turn our attention to interview approach.

**Interview approach.** Semi-structured interviewing practice was central to this study to pursue authentic voice authentically. A well mapped interview protocol was the guide to the research and not its destination. Mapped questions ensured focused dialog and easier data intake, but not at the cost of unanticipated and genuine participant voice. (Merriam & Tisdell, 2015) The research intention was to cultivate genuine understanding through active reflection and dialog towards what is of interest (Seidman, 2013).

Research texts discuss the challenge in accessing the *inner voice* of participants, which the scholar distinguishes from public voice as being fundamentally unguarded and therefore inherently authentic and in the moment (Seidman, 2013, pp. 78–79). Effective interview practice depended on a combination of pilots, respectful curiosity and just enough structure and anchor for the dialog through the mapped interview protocol. The objective was to draw that genuine inner voice forward through honest, safe and respectful conversation.

**Pilot.** There is strong advocacy and rationale for application of pilot interview as practice, rehearsal, and more (Driskill & Brenton, 2011; Miles et al., 2014; Sampson, 2004).
Running interview pilots with two high-tech engineers encouraged a genuinely reflexive approach to study design and execution. Every reasonable preparation to make the most of the research participants’ time and conversation was made.

Piloting interviews to practice delivery and refine the structure of two interview protocols helped develop and improve skills at finding and listening to what is of interest (Miles et al., 2014, p. 42; Seidman, 2013). “Had we conducted a thorough pilot study and given ourselves proper time and resources to fully reflect on the lessons to be learned from such a pilot, perhaps our team might have been in a position to consider the dangers involved in the fieldwork more carefully.” (Sampson, 2004, p. 390). Thus, to think and work merely in terms of optimization of study design would have not have been enough. The researcher must consider all possible impacts as well.

Piloting this study consisted of running both of the IPs with two purposefully selected participants with the necessary constraints of face-to-face delivery. Rigorous practice demanded sufficient reflection before forging ahead with data collection.

Miles et al. discussed the dilemma of study validity versus avoiding harm and the effect on data integrity (Miles et al., 2014, p. 67). Elimination of data from the study reduces, perhaps catastrophically, the capacity of authentic voice. The ethical requirement of simply not doing harm is a fundamental burden to any and all who practice qualitative research sincerely and in a scholarly manner (Miles et al., 2014; Sampson, 2004).

**Collection procedures.** Primary data collection was through face-to-face interviews so that the full nuance and detail of nonverbal as well as verbal responses could be observed and catalogued as field notes (Driskill & Brenton, 2011, pp. 84–90). While the opportunity to
conduct virtual interviews was offered, all of the subjects insisted on face-to-face interviews. The objective in collection was comprehensive and thorough capture of authentic voice while bracketing out researcher bias and preconceptions of “good” answers.

For this study, this researcher collected data as a participant-observer (Driskill & Brenton, 2011, p. 84). Appendix F details semi-automated interview transcription, recording redundancy, and data collection and curation tracking. The use of an explicit data collection checklist helped ensure ethical rigor and data collection practice for all phases of scheduled collection as shown in Table 3.1

Table 3.1 Scheduling data collection for the study

<table>
<thead>
<tr>
<th>Data Collection Scheduling</th>
<th>Timeframe</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interview Protocol Adjustment</strong></td>
<td>Prior to collection</td>
<td>Pilot interviews @2 participants towards revising interview questions</td>
</tr>
<tr>
<td><strong>Recruitment</strong></td>
<td>Week 1</td>
<td>Purposeful selection, obtain consent forms, conduct inbound participant writing prompt</td>
</tr>
<tr>
<td><strong>Primary Data Collection</strong></td>
<td>Week 2 - 3</td>
<td>Schedule and conduct interviews, transcribe and perform first cycle coding, perform member check via email</td>
</tr>
<tr>
<td><strong>Secondary Data Collection</strong></td>
<td>Week 4 - 5</td>
<td>Review primary collection for saturation, conduct outbound participant writing prompt, add prompted writing data to database</td>
</tr>
</tbody>
</table>

Participant essays were offered to augment and supplement primary data collection in alignment with Seidman’s thinking on multiple participant contexts (Seidman, 2013). None of the subjects chose to complete the inbound writing prompt while only two submitted written responses on exit from the study. Verbal engagement is not a cultivated focus within the profession, and supplementing primary interview data collection with an inbound and outbound
writing task offered subjects an alternative means of expressing voice and story. Appendix E contains samples of inbound and outbound participant writing prompts.

**Field notes.** Committing to field notes helped bracket out biases, distortions, and preconceptions by eliminating the need to remember and recall versus simply looking at the captured snapshot of impressions in the moment as a written or audio note (Driskill & Brenton, 2011; Miles et al., 2014; Seidman, 2013).

Keeping a research journal was a natural and sensible extension of this practice as another way to encourage reflection and reflexive adaptation to the study’s needs (Lincoln & Guba, 1985; Seidman, 2013). Following suggested practice, a reflexive diary and a methodological log in depth and in detail became important artifacts of data collection and analysis (Lincoln & Guba, 1985).

**Data storage, archival, and encryption.** For the purpose of primary data collection, all interviews were recorded using the Rev app as well as a secondary device to preserve the participants’ time and to avoid data loss. Curation of the recorded interviews consisted of transferring them off the recording device into a password-protected device as both backup and secure storage. Archive of the curated data was on a secure SSD drive that was encrypted. Removal/wipe of unprotected files from both recording devices was performed on completion of that archival process.

Writing prompts as secondary data collection for participants was subjected to the same secured discipline when they were submitted. They were marked confidential and private within email and directed solely to the researcher’s university email address. The results of the prompts were archived and curated in the same manner as the primary data.
Here we see both protection of the participants’ time and confidentiality in evidence. Backing up a copy of primary data collection sources seemed inadequate. Encrypted archival was a far more responsible and appropriate procedural choice. This is not to say that failing to encrypt backup backups and primary data collection artifacts is unethical; it is merely a better practice to encrypt them.

Professional transcription through Rev not only saves time but also imbues a small degree of external confirmation of the data collection itself. All electronic and printed artifacts of primary and secondary data collection were transferred to encrypted archive on ingestion and on completion of professional transcription. In accordance with best practices of secure data handling, no loose materials, whether they were physical or digital were left behind. All data collection elements were encrypted during data collection and destroyed on completion of the study.

**Data Analysis**

Analysis of the collected and curated data was synthesized through parallel, ongoing condensation, display, and conclusion drawing. Research method sources align on the induction of such patterns and concepts recursively from qualitative research data (Miles et al., 2014, p. 12; Polkinghorne, 1995). Analysis of the study data followed Miles et al.’s steps of condensation, display, and verification towards drawing conclusions. These three workflows were ongoing and cyclical throughout data analysis.

**Data condensation.** Condensation of data required categorically grouping on intake while searching for preliminary patterns and can be expressed as *enumerative induction* (Miles et al., 2014, p. 292). This transformation of the raw study data was through codification,
summarization, and openness to emergent theme in alignment with Seidman’s data immersion practices (Seidman, 2013). It began the moment data collection began.

“Once the interviews commence, the researcher cannot help but work with the material as it comes in.” (Seidman, 2013, p. 116). Data condensation occurred immediately on intake classification and continued throughout all phases of analysis as needed to distill authentic experience into understanding.

Disciplined and rigorous approach within the IP design enabled systematic flexibility, allowing those authentic voices to be heard more clearly across all collected qualitative data (Miles et al., 2014; Seidman, 2013). Seidman instructs that “To work with the material that interviewing generates, the researcher first has to make it accessible by organizing it.” (Seidman, 2013, p. 115).

Organization of the raw data was inclusive rather than exclusive; “the first step in reducing the text is to read it and mark with brackets the passages that are interesting” (p. 120). To do that, personal interest(s), identified bias, and acknowledged prejudice was bracketed out to avoid drowning out authentic voice. Therefore, analytic memos, annotation of field notes, and reflexive journaling was actively practiced throughout the entire process from design and planning through to data presentation (Miles et al., 2014; Ortlipp, 2008; Seidman, 2013).

For this study, first and second cycle coding in combination with Seidman’s methods presented exciting opportunities for discovery of theme and outlier through the participants’ authentic voices (Miles et al., 2014, p. 73; Seidman, 2013). Initial analysis on intake of data collection was at the heart of first cycle coding. First cycle codes were evaluated and assigned in context of what the live study data revealed within the lens of OI (E₂D) framework. This was
admittedly a deductive component to the analysis; a necessary place to begin inductive discovery from. Summary data display would serve to enhance that.

**Data display.** Today’s software utilities enable visual summaries and graphical representations of emergent themes through coding cycles. By mapping research questions to interview protocol as a kind of research schematic, findings emerged with clear alignment to them. This helped to bracket out interpretation bias while reducing manual effort, resulting in authentic reflection of the data as themes, patterns, and more emerged.

**Trustworthiness**

At the center of every study is the question of whether or not it is consistent, reliable, and auditable for aspects of design, planning, and execution. This is a central value of rigorous practice in research; the capacity to easily identify evidence of that practice in the study. Consistency therefore is as much an active practice as any other element of study rigor; trust in a study is earned through practice of trustworthy methods. Table 3.2 borrows heavily from Miles et al. to address a simple study reliability checklist applied to this study (Miles et al., 2014, p. 312).
Table 3.2 Study reliability and auditability focal areas

<table>
<thead>
<tr>
<th>Study Reliability focal area</th>
<th>Study Artifact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Research Questions are consistently clear and all features and elements of the study are congruent with them.</td>
<td>Entire Study</td>
</tr>
<tr>
<td>2. Researcher’s role and status within the site have been explicitly described.</td>
<td>Chapter 3</td>
</tr>
<tr>
<td>3. Findings triangulate as meaningful parallelism across data sources.</td>
<td>Chapter 4, 5</td>
</tr>
<tr>
<td>4. Paradigms, analytic contexts and constructs are clearly stated and aligned to theory.</td>
<td>Chapter 1, 2 primarily with consistent evidence of connectedness throughout the entire study</td>
</tr>
<tr>
<td>5. Data Collection across the full range of contexts as driven by the Research Questions.</td>
<td>Chapter 3</td>
</tr>
<tr>
<td>6. Data consistency and quality checks against bias and deceit are in place and practiced.</td>
<td>Chapter 3, All Appendices</td>
</tr>
<tr>
<td>7. Multiple observer accounts converge as expected; peer review and/or University oversight is in place.</td>
<td>Entire Study</td>
</tr>
</tbody>
</table>

Methodological congruence has been sought to ensure consistent alignment between the overarching research question and all components of the study as discussed in depth and is in strong evidence in Appendix E (Morse, Barret, Mayan, Olson, & Spiers, 2002, p. 18). Because of the need to pursue authentic participant voice, the foundational components of the research must be coherent. The need for elasticity to pursue “what is of interest” in a semi-structured interview protocol must proceed from a cohesive and strong foundation (Creswell, 2013; Seidman, 2013).

While expressions of methodical rigor will differ between quantitative and qualitative studies, the common need for reliability and credibility in findings depends on methodical rigor being appropriately present to a meaningful degree as a resonant “truth value” (Guba & Lincoln, 1992; Miles et al., 2014, p. 313). The degree of explicit presentation of this must be congruent with the intended audience (Guba & Lincoln, 1992). Therefore, internal validity and external validity controls, contexts, and limitations will be addressed in the following sections.
**Internal validity and dimensions of trustworthiness.** It has been asserted that internal validity begins with crosschecking, and pattern coding encouraged both that and deep analytical reflection (Yin, 1994). Application of pattern codes helped to illustrate alignment as well as misalignment to conceptual or theoretical constructs, causal, and correlative relationships (Miles et al., 2014, p. 87). These were important steps and measures to cultivate trustworthiness in the data and the findings in this study (Lincoln & Guba, 1985).

Credible, dependable findings lead to findings that may be independently confirmed (Lincoln & Guba, 1985). An attempt to correlate Miles et al.’s (2014) internal validity focal areas to Lincoln & Guba’s dimensions of trustworthiness is attempted in Table 3.3. Evidence of these applications in practice are manifest throughout this study.

Table 3.3 *A correlated application of study trustworthiness*

<table>
<thead>
<tr>
<th>Internal validity focal points</th>
<th>Credibility</th>
<th>Transferability</th>
<th>Dependability</th>
<th>Confirmability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Methodological Congruence is evident</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Descriptions are context-rich and meaningful</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Accounts ring true and resonate as authentic</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>4. Triangulation among complimenting methods and source presents convergence in findings</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>5. Data presentation links to prior and/or emergent theory</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Findings are clear, coherent and systematically related</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>7. Areas of uncertainty and limitation are described</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Rival explanations and negative evidence actively factored into findings</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Member checking is evident in practice</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**External validity.** Where internal validity helps assert reliability, external validity determines and ranges applicability. “Even if a study’s findings are valid and transferable, we still need to know what the study does for its participants – both researchers and researched – or its consumers.” (Miles et al., 2014, p. 314). Because of the deficit in qualitative research on high-technology innovation, the opportunity to establish an applicable cornerstone in this area
increased in importance. Thus, external validity remains a critical element for establishing academic resonance and validity.

For narrative inquiry, thick description through widely descriptive data enables a critical element for transferability of findings as shown in Figure 3.7 (Miles et al., 2014; Suter, 2011). Prescriptive guidance on external validity measures can be rendered down to study sample applicability for comparison to other similar samples (Miles et al., 2014, p. 314). Therefore, meeting all conditions for internal validity (Figure 3.6) and the capacity to confirm and extend findings relevantly are foundational to application outside the original samples.

Transferability hinges on relevance to related and potential research as contextual fit (p. 314). In order for findings to be considered for abstraction and generalization, they must be congruent, authentically true, and stated clearly and comprehensively. Table 3.4 addresses additional dimensions of validity for this study to related research.

Table 3.4 Study considerations for transferability of findings

<table>
<thead>
<tr>
<th>External validity focal points</th>
<th>Transferability Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Original sample characteristics are well described, detailed, and diverse so as to encourage comparison to other samples</td>
<td>Essential to transferability</td>
</tr>
<tr>
<td>2 Limits for the study are clearly, explicitly stated</td>
<td>Valuable when possible</td>
</tr>
<tr>
<td>3 Readers conclude that the findings are consistent with similar experiences</td>
<td>Critical Congruence</td>
</tr>
<tr>
<td>4 Findings are in line, extend, and/or confirm prior theory</td>
<td>Essential</td>
</tr>
<tr>
<td>5 Emergent theories and the degree of transferability are explicitly stated</td>
<td>Valuable</td>
</tr>
<tr>
<td>6 Clear statement of further research and testing opportunities</td>
<td>Highly Valuable as evidence of confirmation</td>
</tr>
<tr>
<td>7 Evidence of replication of findings in other studies</td>
<td></td>
</tr>
</tbody>
</table>


**Presentation of Findings.** Coded, adaptive, meta-matrices and linked node displays as networks helped to both synthesize and effectively summarize qualitative case study findings (Miles et al., 2014, p. 109). Attention to format as well as content makes for effective presentation. Visual representations and engaging graphics helped to explain concisely.

Presentation format was intended to be no more than a medium to convey rigorously collected, accurately coded data. Miles, et al. asserts that “conclusions drawn from a display can never be better than the quality of the data entered” (p. 115). Thus, presentation form reflects intent and methodical congruence, functionally.

Discussions of findings, acknowledgement of study limitations, and applicability all flow logically from rigorous design and relevant data collection. Integration and acknowledgement of outlier effects and impacts help to build comprehensive and accurate explanations, as exceptional data both protects against self-selection bias and guides the way to coherent, verified, conclusions (pp. 292-305). The importance of disciplined method was captured by stating that “Technique isn’t everything, but it is a Lot” (Seidman, 2013, p. 78).

**Summary**

This chapter detailed the intention, design, methods, and approaches that were used for primary and secondary data collection and analysis for research into understanding high-technology engineers’ authentic experiences of agile and profitable invention and development. The study purpose is one of exploration and understanding through discovering where possible, the authentic inner voices of self-selecting participants.

The methodology described in this chapter was selected to provide both sound investigative and analytical contexts while establishing a foundation for further research in this
vitaly significant area of knowledge curation and cultivation in the 21st century. An in-depth report of resultant analysis and findings from participant data will be discussed in the next chapter.
CHAPTER 4: RESEARCH FINDINGS

In this chapter a brief profile of each of the six study participants is presented, followed by thematic analysis of the primary interview and secondary writing prompt data collected. Interestingly, all participants strongly preferred face-to-face communications for the interviews. None wanted to make use of virtual communications in the form of phone calls or online meetings. Only Lion and Delta 5 chose to scratch a few lines in response to the writing prompts, which directly aligned with their interview data. Nash and Crius made mention that the prompts helped them to think about their experiences. Their very choice of interview venue and type of participation served to deepen insights into the authentic experience of these high-technology engineers.

Superordinate themes of innovation inhibitors and collaborative invention enablers were identified. In terms of innovation inhibitors, themes of fear of change, poor communication, and complacency vs. competition were pervasive. In context of collaborative invention enablers, themes of welcoming diverse views, creative freedom within relevant goals, and accountable understanding emerged. While some findings aligned with Miller at al.’s work on interpersonal learning in context of the explore/exploit dynamic, other findings were significantly notable, such as the dysfunctional complacence vs. internal competition dynamic.

Participant Profiles

The six engineers who participated in the research vary in years in practice and range from bachelors to doctoral degrees across different science and technology specialties including mathematics, computer science, software engineering, and mechanical engineering. Purposefully selected from different backgrounds for their proven enthusiasm, demonstrated technical
competence and above average communicational skills. Their stories and perspectives on technology invention and development revealed an unexpected convergence of values and concerns across very different work contexts and engineering teams.

**Crius.** Crius pursued computer science and software engineering within the University system in her native country and in the United States through to a Master’s degree. Her combined academic and professional practice in high-technology helped her to select software engineering as her career focus. That choice was reinforced with positive experiences through internships and co-op programs that combine active practice with undergraduate and graduate coursework. For Crius, developing new technology is a means of fulfilling self-discovery and exploration through communities that openly share knowledge. She shared her thoughts on how competitions within and outside of the site build and reinforce that experience:

Yes, there should be Java competitions, there should be C competitions, there should be Python competitions, and that’s how people, you know, of similar interests will come together. They have interests in Python, some others have interest in Java. We come together, share ideas, we share knowledge, and we share the up-to-date technology and are linked and associated with it.

**Delta 5.** Delta 5 is a senior software engineer whose academic background is predominately in mathematics. Having gravitated towards engineering after college, he primarily consulted on different hardware technology systems performance statistics. Delta 5 innovates from factual researcher pragmatically, pursuing solutions with set variables and elements for least cost/greatest performance outcomes. He works to convey comprehensive pictures of
solutions rather than focusing in on just one aspect of a system. For Delta 5, open sharing of practical knowledge simply makes good sense and efficient practice towards desired results:

Open source is usually a quick way to get things done without having to do everything from scratch yourself. A recent example was writing a new performance test [for a specific product]. Really, all of that code was not going to be portable. I thought if I could dig deep into some other developer’s code, it would be 10 times more work, so instead I just did some research. What’s available now? I found a nice tool and instead of writing all the C code from scratch, I was able to just script with Bash scripts, Python, and other much more developed tools.

**Lion.** Lion is a software engineer pursuing an advanced degree in computer science while working in a software development team. Respectful and inclusive collaboration is very important for Lion, who often expressed a sense of enjoyment working with other people. For Lion, a passionate, talented, and invested community is central to engineering development practice. Lion conveyed that such a community must consistently offer mutual respect in kind for all exchanges, and that its absence is a source of great frustration in developing solutions Lion offered candid insight into what was centrally important to a high functioning engineering knowledge community:

I feel like everybody feels very strongly about what they know in their approach to things. Yes, I would say there’s definitely a lot of pride and I feel like a lot of passion in the work that people do and what they know. That could be challenging. Although, it’s really good, because that’s how you diversify the kind
of work that you’re doing. It’s frustrating especially if … you’re working towards the same goal. So, when you feel as though maybe your voice is not being heard, or your opinion is not really being taken into consideration because somebody else wants to voice their concerns above all else [it is frustrating].

**Scribe.** Scribe has a PhD in computer science, and serves as an adjunct university professor while holding a strong leadership role within the site. Scribe’s motivation is strongly aligned with exploration and creation, openly comparing the work of a high-technology engineer with that of an artist. For Scribe, innovation and development is a highly creative pursuit both personally enlightening and validating through the perceptions and feedback of the team. Scribe invests considerable time mentoring both those who are junior to him as well as peers because of a commitment to the importance of building teams. For Scribe, engineering teams as focused communities are essential to effective and profitable engineering practice. Scribe’s years of experience across a variety of technology roles makes the pursuit of new technology inherently collaborative such that value and meaning is measured in the eyes of the beholder:

I always looked at it as you’re able to create something, much like an artist creates a picture. People can appreciate it and look at it, and understand and provide important feedback. For me, it fulfills a creative piece… It was interesting because when I look at any kind of programming, in my experience, the whole reason why I got into it was for the creative aspect of it. How can I design this to be elegant and fundamentally correct?

**Nash.** Nash is a senior software engineer working in a software development team who conveys great passion and enthusiasm for high-technology. A sense of playful practice in
technological development is very important for Nash and this appears to stem from some of his earliest experiences as a child of five years old, tinkering with rudimentary programming utilities. Nash came to the US to attend University. “I’ve always liked solving problems and I’ve been fascinated with computers and computer programming since before I could remember, right?” Nash shared that a deep love of being challenged and “solving problems” is central to invention and innovation practice. Nash conveyed the importance of cultivating a smart community of coworkers where brutal honesty, candor and recognition for excellence is paramount to mutual success and fulfillment. Nash’s experience and facility with technological constructs and languages aligns with the expressed love of stimulation and of highly visible challenges that make a meaningful difference to peers and end-users alike. For Nash, difference of views and openness to mutual critique within a community of practice that is willing to be “brutally critical of your work” is key:

It takes a lot of openness to accept it, and once you get there you begin to realize that it really helps siphon the forces of all those brains and channel it into making a project better. Because as good as developers are today, they still make mistakes… I love surrounding myself with really smart people because I feel like when you surround yourself with the smartest people that competitive nature inside me awakens and it pushed me further.

Tesla. Tesla is a principal engineer working on hardware and platform development. Tesla conveyed the importance of immersion in investigation and innovation, offset by irreverence for the status quo. Tesla shared that ingestion of technical knowledge must be continual, open to all sources, and exhaustive. Tesla knew that “at the age of five… that I was going to be an engineer”. The exact moment that Tesla’s passion was ignited was a PBS special on MIT’s “king of the hill”
competition, where first term students were limited to build widgets from “anything in a box” of parts. The simple objective was to make a device that could go up a ramp and hold on to the peak against another student with the same objective. For Tesla, the innovation process has no choice but to be fully open and actively inclusive where all knowledge is a resource of value:

I’m constantly just ingesting information. I probably spend about three hours a day online reading about technology. I just ingest it. Looking at the world around you and being inquisitive is one of the things I think defines a sentiment being: being inquisitive in nature. It’s the ability to truly hear and recognize the other sentient beings and the world around them. But most people tend to focus too much on themselves.

Prominent Themes that Inhibit Innovation

Interview and research question mapping helped to ensure focused and extend exploration of the central research question. Patterns of innovation inhibitors within and across the individual participants’ narratives emerged as one superordinate theme. The themes of fear of change, poor communication, and complacency vs. competition were pervasive throughout the individual narratives. Table 4.1 relates these distilled themes of innovation inhibition to the central data (see Appendix E for a correlation of interview questions and writing prompts to research questions).
Table 4.1 Distillation of innovation inhibiting themes across the narratives

<table>
<thead>
<tr>
<th>Superordinate Theme</th>
<th>Topic</th>
<th>Category</th>
<th>Prominent Code Patterns</th>
<th>Distilled Themes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovation Inhibitors</td>
<td>Greatest challenges to new Technology</td>
<td>Dramaturgical</td>
<td>Fear of Change, Fear of Blame, Fear of not being Heard, Fear of loss of Status</td>
<td>Fear of Change</td>
</tr>
<tr>
<td></td>
<td>Single greatest hurdle to open technology research and development</td>
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<td>Key challenges to solid knowledge sharing and collaboration</td>
<td>Causal</td>
<td>Complacency or competition (purposive withholding for advantage/apathy). Poor Communication Practices. Loss of Understanding through Communicational breakdown</td>
<td>Complacency vs. Competition</td>
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<td>Difficult aspects of building real relationships and ongoing collaboration</td>
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<td>Poor Communication</td>
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First, the participants’ perception of challenges and hurdles to technology invention and development were consistent and clearly stated as different aspects of fear and disconnection within and of community. Fear, poor communication, and a related dysfunctional dynamic presented through the coding process as formative to their engineering stories. The participants’ engineering practice resonates perseverance, a thirst for meaningful self-expression, understanding, and recognition within communities of peers. Thus, these deficiencies and deficits in collaboration and community align with the participant’s closely held personal beliefs and values, which interestingly converge across different backgrounds and experiences.

**Fear as the muffler of shared knowledge.** Fear of change, of losing voice and respect within the engineering community, of being invisible, and fear’s effect on understanding and communication were expressed as the largest hurdles and challenges to inventing and developing new technologies. All participants, across multiple genders, age ranges, ethnic and racial identities identified variations of fear of change as central inhibitors to open innovation and knowledge sharing. Fear of change was defined very broadly within the individual narratives, but always in proportion to risk and reward opportunities. This emerged as a consistent theme across all the participant narratives.
Crius discussed fear of change as impact in practical terms of project work. Having to set aside preferred tools and utilities that are often fundamental to an engineer’s self-perception of value through contribution was just one manifestation of this fear. “Your performance will be off for that” Crius said. “What did I do significantly?”

Just pursuing a new idea can entail an undefined volume of work which has ripples throughout what was once a well-understood body of technical knowledge. Undefined amounts of work are a telltale in high-technology for poorly defined projects that are short on structure and long on blame when expectations and results are out of alignment. This was expressed as a source of stress and worry from the risk and exposure. “You try and look at it from each and every point of view to figure out what it could cost.” Crius explained the connection between undefined volumes of work and fear of change:

I think it’s the biggest challenge [being] afraid of change, fear of change... I think that when the people innovate and are used to loving or using a particular tool; for example I’m using some version of JAVA. Now I have to update it because the other components are not… They’re going to get updated.

At the same time, you don’t want to update it because it has dependencies. You’re not sure if once you’ve updated those dependencies [that they] will act well. Then you have to deal with those changes. Constant change will lead to constant work…

Crius simply did not want the additional risk, stress, and uncertainty connected to vague development projects. “We have tools to help develop in an agile and collaborative environment. At the same time, you don’t want to agilely develop your functional requirements.”
Nash spoke of the fear of being seen as not keeping up with the intellectual pace of the rest of a team, as being seen as the weakest link. "You really have to be the lawyer of your ideas, your ideas can’t be stupid." Nash discussed how fear of loss of status steals voice and creativity, inhibiting the ability to ask questions that others may or may not have thought of:

Being wrong in a room is not the worst thing. It is better than being silent. Being in silent dissent with an idea presented openly, I think, is a worse thing to do than to openly argue even if you are quote, unquote, the idiot in the room that just doesn’t get it.

To Nash, this tentative lack of open debate within community is stifled creativity because “your ideas can’t be stupid”. In addition to directly experiencing and observing fear of loss of status, he saw that in this vacuum of healthy disagreement, chain of command becomes the usual fallback practice because “You need to show results, you need to move forward, and it’s hard to just wait for this open debate to happen…” For Nash, silent dissent from being afraid to look unintelligent in peers’ eyes blocks access to new and better ways of seeing things.

Tesla and Scribe separately came to similar conclusions about the effects of fear of loss of standing and perceived worth to the team. Scribe stated clear personal preference for open, creative dialog towards gains in understanding, but that not all share that belief:

You really try to come up with creative ideas, and you say “well what do you think? And what do you think?” And that is looked upon as weakness in certain cultures.

Tesla simply asked how innovation could work in a fearful, siege mentality.
So how do you ask someone to go out on a limb and think outside the box? So how do you ask people to take a leap of faith for you when they have no faith in you allowing them to stay in the village?

For the participants, perceived standing in engineering teams is tied to continued employment. Because of the drive for good solutions that can be exploited, less than optimal approaches are constantly weeded out.

Fear of change, fear of being the weakest in the knowledge community, fear of being blamed for missing concrete deadlines within poorly defined projects all paint a picture of inhibited open knowledge sharing and innovative development. Fear mutes strongly motivated voices in the pursuit of understanding and mutual success, thereby affecting communication practice which in turn begets more isolation and fear. No news appears simply to not be good news in the business of high-technology innovation.

**Poor communication practices.** It would appear from the narratives that communication or its absence is at the very center of technical knowledge cultivation. Perceptions of being other, of being a risk to the status quo, and of basic oversights can impact sharing and succeeding. The ability to simply be heard when offering contribution to old problems and new directions in technology and the lack of sufficient informational background on a new problem can cripple innovation.

Crius said simply that “clear communication gives good result” where her worst experience(s) happened when coworkers simply chose not to share full context and background. Crius further offered insight on impacts when entering a new project to learn process from a more experienced peer:
If the person knows a lot, or basically does not have to be told about what has to be done, all goes well. But if the person is comparatively new to whatever has been going on [within the project], it should be properly communicated as to the start and the end point of what is required and what we do already. What is already being done? What do you already have to do?

Crius intimated that the development projects that she’s worked on have been thwarted by people passively or actively withholding information with the result that “I just tried to reinvent the wheel”.

Different engineering teams follow different variations of agile development processes and have different ways of communicating ongoing work within the team itself. When these processes weren’t shared on entry into a project, Crius experienced significant frustration.” It was very frustrating because I came to the situation with an open mind and heart and the other person for whatever reason… They just didn’t want to share.” Understandably, absence of communication, of sharing technical knowledge left her feeling anxious.

For Delta 5, comprehensive and transparent communication is foundational to successful technical development.

I’m doing a lot of research on the cutting edge technologies, and I have more of an individual role, so it’s important that when I have results that you communicate it clearly and not only communicate it clearly but give contextual information.

Delta 5 went on to share that because of the incisive and analytical nature of his contributions, which other team members sometimes see as a threat to their status quo and smooth operations, he has had to deal with deflection and diversion from important technical points. “It’s important
that you communicate [results] clearly and not only communicate it clearly, but give the contextual information”. The absence of this context and clarity makes for consistently poor communication which he perceived as thwarting effective development.

I can show a graph in a meeting and if it’s not labeled right, if it’s too crowded, if it’s not in context… you want to be able to share a picture, right? It’s worth a thousand words.

Scribe’s experiences leading engineering teams led him to assert that “I kind of have found multiple things that work and don’t work through software development and lifecycle practices and engineering”. For Scribe, dictatorial leadership statements stifle opposing perspectives, such that people just seek to appease the leader.

Scribe’s narrative interwove communication with team identity and success. Collaboration gets short circuited when team members are afraid to be straightforward: “I find that any kind of communication, doing it direct, is best in trying to work through that…I think this is where the team concept comes into play…”

Lion expressed deep frustration over not being heard, being cut off and effectively stifled when offering a different perspective. “I know that I am not the only one that may feel kind of unseen”. For Lion, certain levels of respect should simply be made available to all and that poor communication can paint a disrespectful picture, perhaps inaccurately. Lion shared that:

Like I said, I try to listen and understand at the same time I am making a point. So, when I feel as though I’m not getting that in return, you come off as pretty disrespectful.
For all the participants, poor communication and a loss of mutual understanding through a breakdown in simple human communication blocks collaborative progress significantly. Respectful dialog derailed by poor communication habits breaks down, not builds a thriving knowledge community.

**Complacency vs. competition.** As successful technology offerings become established technologies, the desire to maintain profit ratios may drive a status quo mindset. Scribe asserted that “… You have people who have been ingrained in the “it works this way.” [mindset] that is the other side to [innovation and creation], the other sort of roadblock that I found with knowledge sharing.” Subjects Crius and Delta 5 identified change avoidance complacency as an intention to avoid work. “Constant change will lead to constant work, a lot of efforts on everybody’s side” Crius said, where Delta 5 perceived that “Getting people to see that the benefit is worth the risk or the opposite.”

Preservation of ego is another contributor to complacency and resistance. Nash expressed concern that engineering egos and fragile self-perceptions render some impermeable to criticism and that when they do receive constructive criticism, it paralyzes knowledge sharing. “Because great ideas transcend all that, and if we’re not accepting of that diversity [of perspective], you’re just reducing your resources”.

Mishandling of resources enables complacency which is toxic to collaborative innovation, and can also create a highly internally competitive posture that drives action but not collaborative, mutually beneficial development. Scribe related a story of one engineering culture that religiously ranked all its employees with the explicit intention of firing the bottom 20%
every year. An atmosphere of internal competition was cultivated and as a direct result a non-sharing culture and engineering practice was established. Scribe related it as follows:

So what they created though was… And by the way, people knew that they did this. It wasn’t a secret. They knew that they did this. It created… What it did, was on the good side, you flushed out the bottom 20% every year, which is fine. You are able to hire great people back on every year. But on the other side, to make sure you didn’t fall into that 20% you competed. And it could be very toxic.…

For example, if you came to me and you said, and we were in this environment, and you said, “Scribe, I need you to help me.” I’d look at you and I’d say, “I don’t have the time. Sorry, I can’t help you…” Because, it’s not your problem, it’s mine. I’m focused on myself. I don’t want to fall into that 20%.

This appears in opposition to a unified, community driven sense of competition to raise the level of contribution for the greater good. At the far spectrum the narrative told a story of internal competition in some engineering organizations that is short on collaboration and communication. Tesla’s insight was that “We see another perspective on knowledge being a very important kind of power”.

The participants’ narratives told the story that tacitly held knowledge that is held as a prized asset is less valuable in application than any knowledge shared openly. Tesla, Lion and Crius expressed variations on the idea that knowledge is power and that it carries a proportionate responsibility to be shared. Tesla stated that there is a “proportionate responsibility to curate the knowledge in all its forms” where Lion simply said “Knowledge is power and with great power comes great responsibility”.

This complacency/internal competition dynamic stems from a central fear that Tesla speculated is tied to perceived self-value.” I think number one is that by sharing information, they are devaluing who they are as an asset.” Tesla described his views on technical knowledge isolationists as a protective and defensive mechanism:

If they value themselves by the knowledge that they hold and by sharing that with other people, they devalue themselves. Knowledge is a commodity that could be traded on, but it does not increase through its sharing. There are people who believe that. I believe that’s one of the reasons that they hold back. It’s their own [intellectual property] IP.

Prominent Themes that Enable Collaborative Invention

A superordinate theme came together from themes of welcoming diverse views, creative freedom within relevant goals, and accountable understanding within and across the individual narratives. Table 4.2 relates these emergent themes to the central data. Despite the differences in the participants’ makeup and backgrounds, it was evident that they shared a certain idealism around the importance of correct and compassionate practice.

The themes that emerged from the narratives around innovation enablement were not always the simple opposites of the inhibitors; crucial elements that define effective and open innovation are not necessarily obvious and intuitive. The theme of welcoming diverse views overlapped with accountable understanding through the idea that respect and mutual support is a personal, individual practice and responsibility rather than an organizational slogan. “Lip service isn’t enough” said Tesla, when it comes to owning our responsibilities to hear one another.
It is vitally interesting that across their combined practice in engineering of 70 plus years, the language of the narrative was consistent and resonant on the topic of enabling effective and open invention and development. Given how specialties within technology give rise to vastly different jargons, the constant use of words like respect, responsibility, passion and compassion are striking and clear. Different views and approaches to practice, certainly, but real commonality on what is valuable and important to mutual success.

Table 4.2 *Emergent themes of invention enablement*

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<thead>
<tr>
<th>Supercollaborate Theme</th>
<th>Topic</th>
<th>Category</th>
<th>Prominent Code Patterns</th>
<th>Distilled Themes</th>
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<td>Collaborative Invention Enablers</td>
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<td>Personal goal alignment to actual practice Interview 1, Q 1</td>
<td>Creative license, Support to think outside the box, Technology as craft</td>
<td>Creative Freedom</td>
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<td>Encouraging openly shared development and innovation Interview 1, Q 2</td>
<td>People connections, Effective solutions through communication, Introspection over egos</td>
<td>Accountable Understanding</td>
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<td>Encouraging open innovation Interview 2, Q 2</td>
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<td>Prioritized correction of cultural hurdles to innovation Interview 1, Q 3</td>
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<td>Satisfaction/frustration in practicing innovation Interview 2, Q 2</td>
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<td>Mutually respectful knowledge exchange Interview 1, Q 8</td>
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<td>Diverse views experienced through career Interview 2, Q 8</td>
<td>All shared knowledge as valuable, Diverse views as solution drivers, Constant learning and mutual adaptation</td>
<td>Welcoming Diverse Views</td>
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<td>Most Rewarding and profitable projects Interview 1 Q 11, 12</td>
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<td>Code of conduct for agile development Interview 2, Q 11, 12</td>
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**Welcoming diverse views.** Crius as clear and direct when asked to address what she would set as her own code of conduct to avoid pitfalls encountered in practicing agile innovation. “They should always be welcoming, because knowledge is something that should be shared and not to be kept with one person, I feel.” Crius went on to describe her own perspective on what she saw as social responsibility within engineering teams:
I have learned one thing that with great power, great responsibility, comes… It comes with great power. You’re in a higher position because you have a lot of power. At the same time you’re met with the person [who] has a lot of responsibility on his or her shoulders or he or she is a very big position, a significant position. Their very much superior to us. We are their subordinates yet we’ve been treated as equal. I’ve also been around people who have chewed me away for having doubts.

To Crius, real knowledge and authority is correctly shared and resides with those who lead by sharing it. Her dialect of English uses the word “doubts” in place of “questions” and she sees those who avoid questions as having nothing much to offer in the first place.

Lion had a similar emphasis on the importance of not just tolerating, but working to embrace different and not always sympathetic viewpoints. “Like I said, I try to listen and understand at the same time.” For Lion, dialog is mutually respectful and open and Lion has suffered strained relationships where others constantly insist on asserting their views over another’s. Not only does Lion strongly dislike being cut off, Lion hates seeing others similarly treated. Lion shared

I’ve been in situations working on a certain project and we are talking about certain things… I’ll be expressing something or even be presenting something. There have been times where I feel like it’s been cut short, period or kind of like,” Oh yeah, let’s move onto something else.” Or, “this seems to be more important.” [than what I have to say]… That’s really frustrating, and I
don’t know if it comes with just being younger and less experienced, or if it’s just the other person’s personality traits…

Rather than simply reflect or amplify in like return, the participants appeared to share a common trait when they would experience less than welcoming perspectives on diverse thought. For each of them, the sense of right and wrong to consistently strive to be the change they wanted to see in others was an accepted responsibility. This capability for self-awareness was summed up clearly and simply by Scribe as he sought to describe the essential elements to be found in an ideal team:

I care that people are compassionate, and they have a solid understanding for other people. I don’t expect, especially out of school, for them to be emotionally intelligent, but I expect them to be aware of their emotions… You have to be aware that how you talk to people is going to affect the response.

Nash’s perspective on the subject of welcoming different views was prescriptive. “Leave your ego at the door, and be open to criticism”. Nash spoke of knowledge sharing as embracing complete honesty on the specifics of an idea, of stepping back and being introspective on one’s own position in the dialogue. For Nash, being welcoming and having a thick skin go hand in hand:

I really liked the environment of the open stack project, it was very high visibility, and people that were willing to be truly critical of your work, which anyone who’s had their code reviewed by me will tell you that I’m ridiculous when it comes to finding nitpicks in the code… It takes a lot of openness to accept
it and once you get there you begin to realize that it really helps siphon the forces of all those brains and channel it into making a project better.

Tesla insisted that an essential code of conduct, of being open to other people’s thoughts, ideas, and perspectives always resolves to one critical point: “as it pertains to, at least engineering, innovation, what not, is that with knowledge comes a responsibility to then pass that knowledge on to others.” For Tesla, knowledge exists as an important kind of power where responsibility is proportionate to that potential for power. In his eyes, the responsibility for cultivation of the knowledge is a very serious trust and stewardship to not just tolerate but embrace differences in views. Tesla expressed this very directly:

Someone else’s idea, whether it’s good or bad is always worth sharing…

Regardless of whether you think it’s a good idea or a bad idea, everything is worth sharing. The second and it’s really only two rules, but the first is everything is worth sharing. The second… is nothing is impossible it just hasn’t been done yet.

**Creative freedom within relevant goals.** Scribe used the term “artist” repeatedly, while Tesla, Crius, and Nash spoke passionately about creativity. For Lion and Delta 5, fulfillment through creating valued solutions was very important. Surprisingly, all participants equated critical satisfaction and fulfillment in their chosen professions and individual specialties in terms of creating things that others could appreciate and value. For the participants, engineering practice pivoted on creative expression through technology.

Scribe’s shared rationale for practicing engineering reflects his views on technology as an art as much as a science: “For me it fulfills a creative piece.” Tesla sees the practice of
engineering as a fundamentally creative expression of how we see the world and how we respond to the stimulus of problems set before us. For Tesla, the intersection of ingested information and passion to both understand the world around him and express a role in it has an active, artistic dimension.

Building things and putting things together… That’s the way I explain things… I mean I see creativity. Typically people that are very creative also tend to have that inner drive to be creative right? The only way people know that your creative is if you express creativity… Creativity is the ability to think outside the box… Creativity is an expression of a passion for what’s around you… For me, creativity is one of the most important things.

Delta 5 accounts a shift in mathematics in college to the belief that high technology is an open-ended and limitlessly inventive area of study. “I switched to math, mathematics I think because computer engineering is so much cooler because you can create anything, right?” For Delta five high-technology offered a unique mode of expression and enablement not possible in more physical sciences.

In mechanical engineering, you have to build this bridge such that will hold this much weight. It’s been done before and you’re adhering to a system that is very tight or very strict on the constraint but with computer science, depending on what you’re doing, you can be completely creative, you can build the bridge from the ground up and you don’t have to worry if it breaks because no one’s driving over it.
For Lion as well, creativity is at its strongest when it is turned towards relevant results. “I want to work on things or make things that people want to use.” Relevance to those who are consuming what was created is always central. To Lion, engineering practice is about applying science to meaningful results.

It’s pretty cool when you get to work on or do something that didn’t really exist. Or, some version of something that nobody really has [but wants]. That’s the cool thing. That’s what keeps me interested in this field.

Crius sees that a spirit of play in the form of contests stimulates creative intentions while drawing in different perspectives and celebrating those different and diverse views in the world. Crius stipulated that business value as relevance should remain central to such contests. “…These kind of contests, they generate a lot of projects that is very good for the business value.” Crius outlined a focused creative exercise as a means of finding essential engineering skills while celebrating different ways of perceiving solutions.

But I would just like a contest that would particularly lead to a particular technology you see something… You know you give a particular project and you ask for different people to develop the same thing. That will also be something that, you know you get a lot of different ideas, lots of perspectives, and then you can just add all of those important features from all those ideas and create that for a product.

To Crius, such an approach is justified because the community determines the value and the features of the product. It injects relevance in what is created.
Nash similarly envisions diverse creativity as both amplifying and focusing high technology invention and development. “And so you’d have different creative ideas being shared, different critiques of how code was written, how it could be done, and things like optimization…” Nash’s discussion of creative freedom as a tool for focused productivity assumes that engineering teams embrace different views on problems and challenges that are commonly understood. This is more than simple ingestion for Nash, it is the active practice of reflection towards understanding.

**Accountable understanding.** In discussion of what enables fulfilling and effective invention and development, the participants’ narratives touched on the importance of every engineer to practice not just tolerant communication but collaborative communication towards understanding. This was of course expressed very individually and interlocks with their statements on responsibility and compassionate inclusion. The answer can never simply be assumed to be certain and obvious in engineering practice for the participants.

Nash said that “good minds disagreeing is how you solve problems”. The participants individually described different components of a kind of stewardship in the cultivation and creation of shared knowledge. What emerged from the narratives was not a discussion of personalities and skills but a discussion of the importance of the individual participant to both understand and introspect on what they and others were offering in pursuit of technological innovation. Nash offered that “If you feel like your ideas are not being understood you must really introspect and thin about why they’re not being understood.”

Tesla spoke of the importance of understanding as everything expressed is a kind of language unto itself. “All of what I do, I compare everything to a language. Everything is a
language.” Tesla identified the practical impacts of people not understanding other’s perspectives to basic understanding. “The disconnection there is a lot of people just don’t know the definitions of those words… People get too hung up on the definitions and the way to say things as opposed to the point of saying things.” For Tesla, introspection is active and accountable understanding of others.

Tesla expanded on this in terms of technology’s capacity to augment communication but not replace it:

I mean as humans, we are social creatures. We’re social creatures that have given up 90% of our ability to be social. I think it does inhibit. I think technology is something that doesn’t replace, it augments…. The ability to do asynchronous communication – augments communication and it adds to it. It’s not a replacement because our brains are not wired to do solely asynchronous communication.

This technological capacity, Tesla explained, can extend humanity’s reach toward one another, but cannot hope to replace our need to understand one another, to have each other’s positionality as a critical point of reference in interpreting one another.

Yes. It augments. It adds too. It expands that capability, so it expands our capability to communicate with more people, to connect with more people and what it should do is give us the opportunity to connect with those people in person. [Creating] working relationships with those people. Personal relationships with those people, [so] that when given the opportunity to meet in person we take
those opportunities to meet in person and communicate in person is much more effective.

To Tesla, who prizes ingestion of raw and unbiased facts so much, that he reads reference materials in libraries, human connection is fundamental to mutual understanding.

Now when you’re trying to develop and construct with a group of people, when you’re using group creativity to try to construct something, to try to build something, if you do it remotely, you have given up 80% of your ability to do that.

Lion’s perspective on collaborative understanding offered a surprising finding: the community, the engineering team isn’t just the builders, it is the consumers of what is produced. For Lion, inclusion of the solution consumers, the “end users” is key to ensuring accountable relevance. To Lion as well as Delta 5, this orientation to relevance was expressed as central to enjoyment of the work itself. Lion described this as forming a connection with others:

Yeah, the people connections have been great. The collaboration, I would say, is huge for me. Because, like being able to work with people that know more than I do, or even people that we could share our different ideas or perspectives with, well, that’s huge. Because I would say if I worked, let’s say entirely by myself or in a field where the collaboration was far less present, I would say work would be a lot less enjoyable.

Scribe felt that understanding of a common strategy meant accountability for a central vision, while allowing and encouraging different views on how to arrive at that central vision at the same time. To Scribe, developing engineering teams is central to effective development.
I think everybody needs to be aligned in the sense that they understand the goals, understand the strategy. They get the vision. I don’t think everybody needs to be on the same page in the sense that how we’re going to do something can certainly be different.

Scribe’s perception of accountable understanding emphasized creative freedom of approach to commonly shared and understood objectives.

Nash similarly perceived mutual understanding as an ongoing process, and not always a smooth one. For Nash, clashes over design elements and implementation options are inevitable. To Nash’s competitive orientation, how meaning is negotiated makes the difference between understanding and building collaboratively and effectively and stagnant approaches and missed opportunities to push and explore.

I think what I’ve seen get in the way of building technology innovation is if there is a clash of ideas it might be that I wanted technology choice A or implementation choice B of design choice C. It really doesn’t matter but when there is a clash of ideas very often you have people falling silent and differing to authority.

To Nash, difference of opinion and views drives movement towards better results. Nash is a strong advocate for structured and rigorous discussion on difference in approaches.

I would like to see open debate encouraged, right?... Good minds disagreeing is how you solve problems, how you come to compromises, and if you don’t openly disagree, then you cannot debate and you cannot come to solutions.
It appears that the practice of accountable understanding enables effective and mutually beneficial social construction of meaning and value for Nash, Tesla, Lion, in fact for all the participants.

**Summary of Findings**

The research participant’s narratives demonstrated consistent patterns of critical elements to enable fulfilling and effective high-technology invention and development. All participants expressed the importance of welcoming differing views and perspectives, not merely tolerating them. Where some such as Nash, Crius, and Tesla explicitly stated that it is those differences on perspectives that fuels creativity, others assumed that importance such as Scribe and Delta 5.

Surprisingly, creativity was identified as a foundational attribute for good engineering practice in development and innovation and as a centrally fulfilling rationale for the pursuit of high-technology careers. As engineering is a practice of applying solutions towards specific outcomes, the importance of anchoring in relevancy towards positive social gains and effectively lead development as socially constructed meaning evidenced.

The individual practice of inclusion was expressed in the narratives as an accountable stewardship, as a means of balancing power and responsibility through shared knowledge. An unanticipated yet appropriately technical analysis of effective communication habits in both obtaining a point of reference for others’ perspectives and as negotiating meaning socially emerged. The importance of civil disagreement seems a natural extension of embracing different views.

Participants described negative impacts to critical knowledge sharing and development in their own terms and language. Fear of change evidenced and included variations of devalued
standing in their own respective work communities. The absence of clear communication ranged from outright exclusion and choosing not to share to simply poor habits that consistently subtracted from collaborative development of new technical knowledge.

A new and toxic dynamic emerged as complacency versus an internally competitive and unsharring mindset. Toxic exchange geared to strangle new ideas and opposing views showed that knowledge, when perceived as a tool of control becomes a static asset that can only reduce in value. Central to this inhibiting practice is the assumption that sharing and cultivating knowledge equates to giving it away. The implication in this philosophy of non-sharing is that knowledge must remain hidden and exclusive which interweaves with fear-based on poor communication themes of impact and inhibition.

Figure 4.1 visually summarizes the superordinate and distilled themes from the narrative. Innovation inhibitors appear as reflexive rather than introspective and reflective elements that interlock to grind out a stagnant, status quo. While not always the simple and intuitive opposite of the inhibitors, collaborative invention enablers overlap and intersect towards increasing relevant and meaningful innovation. In the next chapter, we will discuss these findings and their implications for practice and future research.

Figure 4.1. Emergent themes in the study.
CHAPTER 5: DISCUSSION OF RESEARCH FINDINGS

This study employed narrative inquiry and a composite framework to explore and understand the authentic, lived experiences of high-technology engineers while practicing agile and profitable invention and development. Enablers and inhibitors of innovation can be found in the authentic voices of the engineers as they practice their young science (Miller et al., 2006; Schwandt & Marquardt, 2000; Seidman, 2013).

This study focused on the central research question: How do high-technology engineers in a global firm describe their own experiences trying to practice agile and profitable invention and development? Appendix E details supporting questions designed to extend and deepen the core research question so that mapping and alignment from research question to interview protocol could be made clear and precise. This effort towards precision in turn enabled focused exploration.

Two superordinate themes were identified within this study concerning Innovation Inhibitors and Collective Invention Enablers. In context of innovation inhibitors, three separate themes as Fear of Change, Poor Communication and Complacency versus Competition emerged. In context of collaborative invention enablers, the themes of Welcoming Diverse Views, Creative Freedom within Relevant Goals, and Accountable Understanding were prominent.

These themes comprise substantive answers to the research question. We may infer some corollary and interconnection across and within the two primary themes. Ultimately, what is of interest is what was found that encourages and enables authentically practiced technological innovation for the six research participants.
We will first turn our attention to the discussion of the three major findings in context of the literature and the composite framework OI (E\textsuperscript{2}D). Then we will address implications for practice and for research. A discussion of the limitations of this study will follow and finish with conclusions.

**Welcoming Diverse Thought as Stimulus**

The seminal definition of open innovation is expressed as “the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation” (H Chesbrough et al., 2006, p. 1). The readiness to actively adopt new, differing, and diverse perspectives to expand and accelerate profitable knowledge exploitation is central to this idea (Florida & Gates, 2002; Hewlett, Marshall, & Laura, 2013). Further, it proves to be a vital stimulus across closed organizational borders and elite research and development groups (H. Chesbrough & Brunswicker, 2014; Davidson, 2011; Miller et al., 2006; Weiblen & Chesbrough, 2015). This study identifies the need of this practice within similar engineering teams and groups in alignment with study participants.

**Diverse views and knowledge sharing.** Miller et al. work to integrate March’s explore/exploit dynamic as an antiseptic, decentralized process that exists outside the influence of organizational codes (March, 1991; Miller et al., 2006). By injecting the shift of tacit to explicit knowledge exchange into that dynamic, a rudimentary capacity for social evaluation of phenomena is outlined (Miller et al., 2006; Nonaka & Takeuchi, 1995). While sound in principal, it begs application and extension beyond the scope of this study.

This extension of diverse views is present and vibrant across different organizational communities of practice and therefore both relevant and intuitive in application. “But new
research provides compelling evidence that diversity unlocks innovation and drives market
growth…” (Hewlett et al., 2013, p. 30). “The key to success in the knowledge-based economy is
what economists call high human capital – what most of us would call talent.” (Florida & Gates,
2002).

Based on the participants’ narratives, acceptance or rejection of differing views is much
more than an antiseptic exchange such that shared knowledge may only grow by embracing
different perspectives and positionalities (Davidson, 2011). The participants shared that it is a
matter of actively valuing every idea, every perspective, every possible differing and non-
aligning insight. In this context, it would appear less a graceful spiral than a series of small
collisions of differing views and perspectives (Nonaka, 1994; Nonaka, Toyama, & Konna,
2000).

The participants conveyed that those who choose not to share personal ideas, questions,
and insights or choose to reject them throttle innovation and development in its crib. The
participants implicitly and explicitly made clear that all knowledge and thought has value,
especially when the desired outcome is new and hasn’t been done yet. The central argument of
accepting all views is less financially motivated than a practical and eclectic exploration for
positive results: if it hasn’t been done yet how can one know what will or will not work?

The participants identified layers of diversity and inclusion beyond demographics and
statistics based on race and gender. Perception of diverse thought is both the goal and the drive
mechanism of working to socially construct and generate new knowledge and to extend existing
knowledge with fresh insights. Inclusion of any and all across race, gender, religion, and
ethnicity is fundamental to having access to that wealth of diverse and differing perspectives.
The expectation is that by offering respectful and equitable weight of possibility, others should similarly reciprocate and thereby enable a positive and adaptive dynamic for active sharing of knowledge. It relates a foundational code of inclusion, of correct and responsible engineering practices and the pursuit of high-technology invention. All must be heard, and all must be understood. How else to progress together?

**More than the simple sum of individual perspectives.** The participants in this study convey that the heart of true shared engineering knowledge is compassion beyond the simple mechanics of knowledge sharing, a deeply held personal feeling that all knowledge is valuable, and expectation that without being self-aware one cannot be aware of the contributions of others to a common goal (Miller et al., 2006). For the participants, it is an active and reflective day to day practice, crippling in its absence. It would also appear that these collisions of differing perspectives are the fuel that powers effective and profitable technical knowledge curation (Davidson, 2011; Ozgen, Peters, Niebuhr, Nijkamp, & Poot, 2014).

But the practice of actively shared knowledge through welcoming diverse perspectives is not one of pure sentiment but rather one of disciplined pursuit of knowledge towards positive solutions and profitability (Henry Chesbrough, 2003; Florida & Gates, 2002; Miller et al., 2006). Organizational goals may be exploration or exploitation for profit; the participants’ shared experiences with innovation indicate that the effective path to those goals is the same such that investment in human capital appears to precede knowledge asset creation (Henry Chesbrough & Crowther, 2006; Florida & Gates, 2002; Hazy, Tivnan, & Schwandt, 2011).

The participants identified the importance of leaving the engineering ego at the door, and like scholarly bias, it is easier said than done (Machi & McEvoy, 2009). Sharing and growing
high-technology knowledge demands an ongoing and active stance of accepting and introspecting on honest criticism of ideas offered, dissenting and differing views, and more. Thus we see that welcoming diverse views requires a balanced and actively reflective practice when engineering high technology solutions. It is more a skill to actively practice and improve than a static position to inhabit based on the narrative.

Put simply, for the participants, shared knowledge is neither a noun nor an antiseptic asset; it is a verb. Shared technical knowledge is perceived to be an organic and ongoing exchange of what may be possible towards a clearly defined and common goal or set of goals (H. Chesbrough, 2015; Flanagin et al., 2010). It is not a discrete unit of knowledge as finished artifact, it is the act of actively knowing and expanding on possible solutions as part of accountably negotiated meaning.

The narrative appears to convey that shared knowledge’s power in high technology invention and development is proportionate to the responsible, welcoming care exerted in its creation and cultivation. Based on the authentic experiences shared by the participants, hoarding knowledge implies that knowledge cheapens when it is openly shared. The inverse in fact is proven to be true in the knowledge economy of the 21st century as upheld by the theoretical framework of this study.

**Creative Freedom as Motivation and Method**

The literature and the OI (E2D) framework both are predicated on the assumption that the dynamic intake and output of shared information is capitalized by need solely for the purpose of becoming a strategic, monetized set of assets (H Chesbrough et al., 2006; Kong, 2010; Miller et al., 2006). This study has begun the critical task of examining central motivation of engineers
within high technology invention and development beyond phenomena in either the “fascinated by technology” or the “technology as artifact and monetized asset” camps (H. Chesbrough & Brunswicker, 2014; Flanagin et al., 2010; Noble, 1984). It is a task that no one study can complete.

This study’s exploration of authentic voice and experience in innovation for the six participants surprisingly and interestingly shows a common human element in the active pursuit of imagining and inventing solutions and paths to the future. The impulse to create in response to the world around us, to understand and to be understood is among the most fundamental human needs. This appears to be no less true in the pursuit of high-technology for the participants of the study.

**Creative freedom within relevant goals.** All participants spoke compellingly and earnestly of personal and artistic satisfaction and fulfillment as motivation in terms of how they view the world. Authentic experience shared within the study narrates a need for understanding, relevance, and shared creation in the pursuit of technical solutions.

There was no discussion of patent counts, abstract constructs, or other esoteric artifacts on the subject of personal fulfillment in high technology innovation practice by the participants. They instead spoke with feeling about creative fulfillment, of making things that people need and want as a means to engage in dialogue and understanding within a community. These participants resonated as participants in a new Renaissance electrified by discovery rather than just skilled workers and Newtonian cogs in an organizational machine (H. Chesbrough, 2015).

But just as Renaissance artists knew the importance of their patrons, so did the participants express appreciation and a desire to work more directly with the people and
audiences that consume the solutions and products that they invent, develop, and support. Creativity within relevance and a shared common vision of result was consistently present throughout the narratives. This idea of creativity in high technology as an expression of passion for the world around you appears to divert strongly from stereotypical views of engineers as detached, self-contained tinkerers (Robben, 1999).

Interestingly, the literature aligns and supports this study’s findings on the importance of diverse thought as creative fuel for new technological invention. Forensic analysis of the Internet itself in the literature reveals it to be a socio-technical, self-evolving construct that grows based on diverse inputs and internally generated new knowledge as reflection of the audiences that use it (H. Chesbrough, 2015; Flanagin et al., 2010; Weiblen & Chesbrough, 2015).

What is missing in the OI (E²D) framework is not awareness of the importance of individuals, organizations, and groups as social contexts, it is the apprehension of the role that creative motivation as relevant self-expression plays in creating new technologies (Land, 2013; Tabeau, Gemser, Hultink, & Wijnberg, 2017). Technological business contexts can only benefit from promoting genuinely creative cultures where risk's reward is the opportunity to learn from mistakes and apply and extrapolate beyond the immediate lesson (Sirén & Kohtamäki, 2004).

Sharing innovation openly as a paradigm is not always synonymous with permeable insights into technological advances (H. Chesbrough, 2015; Chiaroni, Chiesa, & Frattini, 2011). Perhaps technological creation is more than the sum of linear experiences, efficiently exchanged, cataloged, and amortized. Perhaps creative freedom enables effective innovations towards depth and variety of relevant options (Tabeau et al., 2017).
For this study’s participants, artistic expression and defining positive, common paths to tomorrow evidence as more than the monetized opportunism relayed in both literature and the core framework of the study. It speaks to a positive and inclusive futurist vision as human and passionate response to the needs of human society and the world. Certainly, relevance is ultimately measured within a business as profitable invention and development. For the participants of the study, the personal and interpersonal layer is so much more than just the execution of tasks as part of a job.

**Creative freedom and focused, methodical invention.** The participants shared that a spirit of play and beneficial competition resulted in some of their most central and formative positive experiences in engineering development. The clarity of a common goal and opportunity for positive affirmation through shared objectives and clear results emphasizes focused and purposeful invention over assembly-line, status quo approaches.

For the participants, even losing a competition was winning because of the knowledge that would be gained along with insight towards how to refine method and approach. This aligns strongly with the study’s lens as goal (market) driven research and intake of new data (Bowyer & Chapman, 2014; H. Chesbrough, 2015). All technical knowledge is valuable when focused towards relevant opportunity, based on the narrative conveyed.

The OI (E²D) framework’s emphasis is on cooperative competition and balanced exploration and exploitation to uncover new markets as profit venues. We see the human value in pursuit of technology in this fashion through the study. This finding therefore positions at a new interpersonal level within the model (H. Chesbrough, 2015; Miller et al., 2006). The emphasis on the interpersonal impact in other innovation dialogs supports common resonance of it across

This study suggests expansion of the framework’s explanatory power as the adaptive use and active practice of applying creative approaches to fulfill organizational and business needs at the personal and team level. This latitude as creative freedom to attain result aligns with the literature for effective competition through best use of engineering resources (Cheng & Lin, 2012; H. Chesbrough & Brunswicker, 2014; Volmer & Sonnentag, 2011).

**Accountable Understanding as Knowledge Curation**

Both the literature and the framework address purposeful creation and curation of assets at the organizational level. These assets happen to be products and artifacts of shared knowledge as patents, technological solutions, and more. Miller et al.’s extension of the Marchian shared knowledge dynamic addresses organizational contexts in terms of the graceful tacit to explicit shift of knowledge as an upward spiral. Therefore, so must the OI (E²D) model (H. Chesbrough, 2015; Miller et al., 2006; Nonaka & Takeuchi, 1995).

The literature addresses cognition, shared ideas and constraints of available technologies as stressors and more without discussing enablement or inhibition of technological invention in applied practice. It only discusses impacts on awareness and artifacts produced (Berger & Luckmann, 1966; Pfaff, 2012). This study helps to begin to fill this gap of insight into the effective practice of high-technology participants’ through their authentic experiences.

This study gives voice to the six participants’ perceptions around technological limits and individual responsibilities to create understanding through authentic, cultivated connection to
other human beings. Where the literature speaks to stress narrowing perceptions and affecting work output, the participants of this study clearly express discrete elements, components and practices of cultivating understanding of others perceptions in the pursuit of high-technology solutions (Pfaff, 2012).

**Interpersonal curation of shared knowledge.** The narratives reveal a belief in the practice of collaborative and cultivated communication beyond mere tolerance. There is a clear and consistent valuation of understanding views, perspectives, and ideas. The participants describe a type of knowledge stewardship as an essential responsibility implicit in the profession. These six practicing engineers appear to move towards understanding the basis of others’ perceptions and positionalities as a means to access new knowledge.

Surprisingly, there was uniformity in the belief that the best medium was neither technological nor virtual in nature. The participants made clear the importance of face-to-face communication with a heavy emphasis on listening as both a gesture of respect and to help introspect and process other’s input. This commitment to the ongoing dialog of technical construction and invention was common to all participants.

Remarkably, advanced virtual technologies, texting, and simple phone conversation were all seen only as an aid and extension to fundamental human connection within this study. The participants all showed awareness of the role of technology as a secondary augmentation and narrowed subset of the full range of genuine human communication and dialogue. Attaining understanding was said to be impossible without it within the narrative.

The narratives showed a consistent awareness of the importance of nuance, body language, facial expression, senses of irony and sarcasm as fundamental to establishing a point of
reference for interpreting future interactions. The clear distinction between the value of synchronous dialog and asynchronous communications such as email was unmistakable. The desire for connection, understanding, and human context is an undeniable component of the engineering voice for the participants of this study.

While the full communicational depth could be experienced real time, this study suggests that technologically augmented mediums of communication should be used as initial outreach for connection or to share subsets and snippets of thoughts, ideas, and perspectives on technical problems. It is echoic of McLuhan while pushing forward as purposefully focused interpersonal knowledge curation dynamics (McLuhan & Gordon, 2003). The practice of it conveys a highly committed community of practice as perceived by the participants (Li, Chen, & Cao, 2017).

For the participants, understanding the problem and the possible solution options is an ongoing negotiated dialog. It would appear that understanding between engineers is a function of communicational channel depth and completeness where optimal communication leaves nothing to the imagination. The presence or absence of an established point of reference on an individual as a complete person, not an abstracted avatar, was expressed as fundamental to the participants.

The participants likewise emphasized the capacity to practice listening and reflection actively and consistently as part of this stewardship of accountable understanding. This understanding appears scoped within the boundaries of relevant technical problems to be solved through socially constructed meaning as intake and output of data, information, ideas, and concepts (Bijker et al., 1987; H. Chesbrough, 2003; Miller et al., 2006). This is in solid alignment with the lens for this study, OI (E^2D).
The practical ethics of accountable understanding. The participants’ narrative did not stop at an abstracted and idealized event of understanding as epiphany, but rather delved into the practical day-to-day ethics and correct practices of knowledge cultivation and curation within the bounds of forming high-technology solutions. As an ongoing process that emphasizes personal introspection, the participants shared that mutual understanding is neither a single moment in time nor is it always a smooth process. This finding is at odds with Miller et al.’s employment of Nonaka’s knowledge spiral as an explanation of interpersonal knowledge development (Miller et al., 2006).

The importance of not remaining silent in disagreement was a key tenet offered by the participants; silent dissent was considered far worse than possible loss of status among engineering peers for appearing not to actually get the idea at hand. An honest preference for semi-structured open debate was expressed consistently by all participants within the study.

Debate therefore appears as a natural necessary practice for good minds with diverse perspectives wrestling their way through challenging technological problems. This aligns as a natural mechanism to foster compromise and to negotiate the construction of meaning in the presence of diverse and differing views, ideas, and perspectives (Berger & Luckmann, 1966; Flanagin et al., 2010).

Respectful dialogue was conveyed as a particularly challenging topic for the participants, especially since they conveyed that this is not a reciprocal practice as often as it should be. Based on authentic experience shared, it would appear that some engineers allow passion and opinion to override rigorous and structured debate. It would appear that in the rush to solve problems and provide results, structured debate can fall aside in favor of opinions. The narrative does not
provide extensive detail other than to encourage introspection and persuasive communication based in fact as an offset and means to attain understanding through ongoing, respectful clashes of perspective.

This offers suggests extension to the OI (E²D) within this study while subtly and significantly changing it. For the participants, knowledge curation is less a graceful spiral of shifted knowledge than ongoing collision and combustion of differing views focused towards technological solutions and competitive advantage (Davidson, 2011; Miller et al., 2006). All theory must revise in the face of authentic practice and experience.

Is important to clearly note that the study relates that accountable understanding does not produce harmony and homogeneity of perspectives as the result of a shared epiphany. Diverse perspectives are not required to converge in the pursuit of accountable understanding amongst engineers. Disagreement, clashing ideas, and ongoing negotiated meaning appears to be both the fuel that drives creativity and the pipeline by which technological invention and innovation is delivered. The energy released between structured and respectful clashes of ideas and views may in fact drive shared knowledge creation, based on the narrative within the study (Davidson, 2011; Hewlett et al., 2013).

**Discussion of Implications**

Through the lens of OI (E²D), this study simultaneously supports, challenges, and offers possible extension to the model. The participants shared both negative and positive experiences across institutional boundaries throughout their careers to narrate inhibitors and enablers of effective and profitable technological innovation.
Their authentic experiences may help researchers to further understand what is required in the practice of agile and profitable technical invention and development in the early 21st century. The study helps to move the idea of open innovation and the exploit/explore dynamic past an abstracted organizational level theory towards the beginning of understanding the essential interpersonal elements of active, inclusive, and effective technological knowledge creation and curation.

In bypassing the existing practices of measuring the presence of innovation by the artifacts left behind in the form of patents and more, this study explored central motivations, healthy and toxic practices, and interpersonal exchanges and ethics in the pursuit of understanding technical options and solutions to relevant, well scoped problems. Thus, some incongruence with the lens of the study appears, encouraging revision, extension, and deepening of the framework towards greater explanatory power in alignment with authentic experience.

If this study must conclude with a single point, it would be that a unified theory of high-technology invention and development that explains effective engineering practice is indeed possible with sufficient breadth and depth of research. The capacity to understand and ultimately to predict increase in the occurrences of inventive events is feasible. The authentic voices and lived experiences of high-technology engineers in the study offer insight into possible essential elements for that unified theory.

**Implications for practice.** The findings from this study offer insights and guidance in how to foster a greater occurrence of innovation events within Technology through active and reflective practice. To allow pursuit of profitable invention and high-technology without full awareness of the very human interpersonal dimension of the engineers who practice it is
ultimately self-defeating. To be blind to difference, and the needs for creative expression and invested, respectful dialog ensures that the world at large cannot realize the full benefits of a truly permeable and inclusive knowledge economy. Therefore, ongoing investment in refining team and interpersonal guidelines beyond a general organizational model in technology practice appears central to realizing measurable and ongoing successes (Davidson, 2011; Tucci et al., 2016).

The results of the study offer insights into the importance of embracing diversity beyond statistical resource demographics, fostering and supporting a sense of supportive engineering community, and of adopting and upholding critical ethics in the creation and development of shared technical knowledge towards relevant goals and objectives. It is not just the right thing to do; it is good business sense and correct engineering practice (H. Chesbrough, 2015; Davidson, 2011; Florida & Gates, 2002; Schwandt & Marquardt, 2000). This critical challenge cannot be resolved by setting policies and stepping back to see what happens; it must be practiced actively and continuously, refined and improved through projects that tune and triage such interaction (Davidson, 2011; Miller et al., 2006).

The high-technology industry must push past policies and slogans about diversity and commit to understanding the presence of diverse and differing views as the essential fuel of the 21st century knowledge economy. “The new perspective – the extraordinary dissent – emerges because there is an opportunity for improvement and a need to change the status quo” (Davidson, 2011, p. 7). Different backgrounds, races, ethnicities, religions, and genders help to ensure variety in perspectives on technical solution options. Thus, if the name of the game in the early 21st century is rapid and agile adaptation to emerging markets, then fresh eyes and new perspectives are essential to making the most of all phases of technological development.
With that purposeful intake of diverse and differing views comes the need to enable effective creative freedom to meet the needs of those markets, products, solutions and more (Tabeau et al., 2017). Flattening organizational structures and changing compensation models helps to encourage the exchange of information towards objectives, but does not enable, support, and reward truly out-of-the-box thinking. By making engineering leadership accountable for economic and efficient progress to results without dictating the parameters of solution, we can enable greater creativity in all dimensions of technical innovation and development. This also increases the variety and relevance of solutions offered while ensuring that high-technology engineers invest more fully in organizational objectives (Li et al., 2017; Tabeau et al., 2017).

Ongoing mentorship on fundamental interpersonal communication practices for engineers must be developed and implemented throughout the industry. It builds commitment and community where there is little to be found and reinforces that sense of investment that successful engineering teams consistently exhibit (Henry Chesbrough & Van Alstyne, 2015; Li et al., 2017). Seeding teams and organizations with mentors who practice effective communication is an essential first step.

Technology can also borrow from organizations outside of the industry and adopt techniques for engagement that reduce fear of change while building an active eye to incorporate difference and diverse views (Davidson, 2011, p. 157). Projects that seek concrete results for cost reductions simultaneously demand new perspectives without challenging the value of existing legacy technologies and products. This can effectively leverage difference, build accountable understanding, and inject reward through results for controlled experiments as practical work. Not all technological innovation need be new invention; smaller successes build the correct practice habits and set teams on the path for more sweeping successes.
The capacity for introspection, reflection, and respectful exchange on emergent ideas in pursuit of technical solutions is not uniformly practiced or even understood. The idea of accountable understanding found through the narrative of study participants offers a possibility of developing better answers to tough and relevant technological questions through active, educative application. Thus, constructing courseware that supports accountable understanding as a best practice of highly effective engineers can and should be practiced in tandem with individual mentorship and carefully constructed projects focused on measurable success.

Implications for future research. This study’s findings of six participants’ authentic experiences practicing technological innovation encourage further exploration, validation, and improvement upon what has been shown in scope of the study. Quantitative, phenomenological, and ethnographic case study position as possible and plausible research trajectories. The figure shows one such potential research trajectory.
Figure 5.1. Implications for future research: a potential trajectory

Within this hypothetical research trajectory, the project codenamed PD1 focuses on quantitative measurement of the increased frequency of innovation events in organizations that may align similarly to the authentic experiences of this study’s participants. The definition of artifacts of innovation must be similarly expanded beyond patents to gains in delivery cycles, trade secrets, reduction in cost to develop, retention of valued engineering resources and more.

A phenomenological investigation of successful and unsuccessful meaning making within predicted innovation event cycles is the basis for study PD2. It may allow validation and deepening of the nuances for what has been identified and found within the scope of this study.
PD3 is an ethnographic case study that may be critical or interpretive as research into potential enablers and inhibitors of technological innovation progresses. This new study could serve as practical advocacy for truly diverse and inclusive engineering development teams. The study objectives would include assessing for balance between profitability and genuine social relevance within and outside of high-technology contexts. This could potentially assist in deepening the model’s alignment to the 21st century knowledge economy.

These new studies are essential to exploring, confirming, validating, expanding, and deepening the explanatory power and practical relevance of OI (E²D). Assessing and reassessing high-technology engineers’ authentic experiences in the practice of technology must not be a one-time event. If one investigation provides insight and potential extension to existing, established scholarly theory, what might a multi-site case study possibly uncover?

Limitations

While this study offers valuable new insights, it has several limitations. First, the study’s six participants are not sufficient to make a comprehensive statement about all high-technology engineers in all corners within the industry. The permutations and combinations of engineering work cultures alone make a rush to summary judgement precisely that and nothing more. Investigating the increased frequency of innovation events can help to reveal and refine what has been understood through this study.

Second, the study focused on the authentic experiences of high-technology engineers as they pursued financially profitable innovation. This study did not choose to include high-technology engineers in the nonprofit or government research sectors. Motivation, purpose, and intent in context of target audience cannot help but affect and inform engineering practices as
they evolve. The definition of success and targeted audiences for products and solutions drives that practical evolution.

Third, while the study did purposefully select participants based on experience, education, and the capacity to communicate their thoughts and ideas effectively, it did not differentiate based on engineering specialty. The professional focus of an engineering team can bound and define interactions, success measurements, and more. Impacts on the model and capacity for predictive relevance should reveal as research moves forward into multi-site case studies, quantitative measures, phenomenological and ethnographic investigation and more.

**Summary and Reflection**

This study was guided by a central research question: *how do high-technology engineers in a global firm describe their own experiences trying to practice agile and profitable invention and development?* By seeking to explore and understand these experiences within the scope of the six participants, insights into invention inhibitors and enablers were uncovered, allowing greater appreciation of what ethical knowledge stewardship in 21st high technology may appear to be.

A composite framework based in Chesbrough’s open innovation and Miller et al.’s work on the exploit/explore knowledge curation dynamic was constructed as a theoretical lens for this study (H. Chesbrough, 2003, 2015; Miller et al., 2006). The framework, OI (E²D), proved to have sufficient explanatory power to situate the research while being elastic enough at accept surprising new findings that align with and potentially extend it as related in Figure 5.2
Figure 5.2. Study findings inform and potentially expand the OI (E2D) framework.

This specific exploration was explicitly called for within the literature in combination helping to move this corner of scholarly research past rough abstractions and indirect assessment by patents and other artifacts towards a far more rich exploration and potential understanding. It demonstrates that it is possible to attain an understanding of just what effective practice of technical invention and development may look like. This study explored authentic lived experience of high-technology practices through the authentic voice, organizational contexts, and artifacts of six research participants (Martinez, 2010; Moniz, 2012; Priem et al., 2012; Tucci et al., 2016).

Six participants were recruited based on professional experience, education, and the ability and interest to effectively express themselves and give voice as narrative to their authentic practices. As a result of interviews and writing prompts, two superordinate themes emerged from the narrative as nearly polar opposites pivoting around the idea of financially effective innovation.
Innovation inhibitors consisted of three separate themes as fear of change, poor communication and complacency versus competition emerged. Collaborative invention enablers, emerged as themes of welcoming diverse views, creative freedom within relevant goals, and accountable understanding. The findings suggest that diverse views and differing perspectives are the fuel of technological invention and development that requires a constant, active investment in mutual understanding as part of a social construction of technical knowledge. This aligns to the framework described in figure 5.2.

These themes comprise substantive answers to the research question while addressing exploration called for in the literature. While the findings offer an exciting opportunity to further explore and hypothesize predictive conditions for innovation events and high-technology, these authentic experiences alone cannot fully answer what makes and drives the 21st century knowledge economy at the interpersonal level.

This study and the authentic experiences of the six participants it relates encourages and calls for possible new dimensions of understanding of what it means to steward the creation and curation of high-technology knowledge in the 21st century. More research is needed to explore, confirm, extend, and validate the findings of this study. It is up to us to choose to go through that door towards exploration and definition of truly just and inclusive tomorrows for us all.
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Appendix A

Scholar Profile: Chesbrough

High-Technology Organizational Theorist

Chesbrough is most widely noted for his OI model and for coining the term open innovation. The critical thrust of his work is to provide a cross-organizational model of internal and external knowledge creation and cultivation specifically for high-technology firms (H. Chesbrough, 2003, 2015; West et al., 2014). I became aware of Chesbrough’s contribution to organizational theory while working as a senior engineer at Maxtor, a Shrewsbury Massachusetts based disk-drive manufacturer during the early 2000’s. It turned out that Chesbrough had been a senior executive at Quantum, the direct organizational ancestor of Maxtor down to the campus and management team. Stories, word of mouth, and imitative practice of Chesbrough’s ideas both impressed and informed.

Scholar Practitioner Positionality Brought Up Close and Personal

Chesbrough’s work integrates academic theory with years of practical experience in high-technology management, invention, and development. This orientation enabled the architecture, enablement, and growing adoption over time of a wide reaching and elastic theoretical construct (H. Chesbrough, 2015; H. Chesbrough & Brunswicker, 2014). At its heart, the construct serves as a meta-innovation paradigm reaching across sources, (markets, competitors, academia, crowdfunding, and more), technical knowledge assets, (intellectual property, customer input, licenses, open source technologies, and more) as dynamically practiced high-technology exploration and exploitation.
Contributing to both peer-reviewed literature, and books, Chesbrough holds a PhD. From the Haas School of Business at the University of California, Berkeley, where he serves as both adjunct professor and executive director at that school’s Center for Open Innovation. It was through his practice of lectures at corporations like EMC that direct contact and stimulating dialog was first made possible (H. Chesbrough, 2015).

“You sound like a lot of the more obscure scholars I’ve had to read along the way, Jeff,” Chesbrough asserted in a small conference room in a Cambridge, Ma. R&D facility on that seasonable May day, “and you raise some interesting ideas.” (H. Chesbrough, 2015). Being only a year into this doctoral program at Northeastern, this was heady stuff. Calvin Smith of EMC’s Chief Technology Office (CTO) followed up in email to say “(Jeff) Thank you so much for coming – so pleased that you could make it, and that you enjoyed it! I think you had some great dialogues with Henry (Chesbrough).” (C. Smith, 2015).
Hi,

I’m reaching out to you because of your demonstrated interest and ability in technical innovation. I’m not just a fellow engineer and coworker, I’m also a doctoral candidate at Northeastern University. I’m doing a study for my dissertation and would really appreciate your help by participating in it completely anonymously, which will take no more than an hour and a half of your time in total.

The study allows engineers to describe in their own words what they’ve experienced throughout their careers trying to practice technical invention and development. I’m looking for five to eight engineers who can find an hour and a half in their schedule over the next two weeks to participate. Here’s what participation consists of:

- Two half hour/35 minute interviews at two different times, at least a day apart. This can be face to face or over Skype, go to meeting, Webex, etc. whatever is more comfortable for you.
- Respond in writing to some brief questions before and after the interviews.

Please understand that everything you talk about or write about as part of this is completely confidential as academic research. Even your participation in the study will be kept completely confidential. We will work to fit your schedule and availability without impact to your working day.
If you would like to participate in this research and share your innovation experiences, anonymously I ask that you contact me of three ways, however is easier:

- Directly on site
- Call my cell at 401-528-9771
- By email at esposito.j@husky.neu.edu – not my work email, please, so that we can protect your privacy and confidential participation.

I sincerely appreciate the opportunity to hear in your own words what you’ve experienced all throughout your career in technical invention and development. If you have any questions or comments about this research project and you cannot contact me at any time or any of the following:

R.E.L. Brown, EdD, Dissertation Chair and Principal Investigator, Northeastern University.
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C.R. Bair, PhD, 2nd Reader, Northeastern University.
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Thanks again for your time and interest in technical innovation; look forward to connecting with on this.

Much appreciated,

Jeff Esposito
Appendix C

Sample Interview Script

Introduction: I want to thank you in advance for your time to be a participant in my interview. I’m a doctoral student at Northeastern University and this interview is part of my dissertation research. Before we begin I want to review a few things:

- First, I want to assure you that all information will remain completely confidential and anonymous. I will be using a pseudonym and I will not include any information that will make your identity identifiable.
- Second, I’d like to ask your permission to tape-record this session. I will be preparing a transcript that I can email you for your review before it is used for the course project.
- Third, the interview contains eighteen (18) questions which should take us about 45 minutes. At any point, if you’re uncomfortable with a question or need me to rephrase, please feel free to let me know.

If these conditions seem agreeable, then I’d like to review these consent forms with you before we begin. Your participation is completely voluntary.

[Review and obtain signature on the consent form]

Thank you very much; let’s begin, shall we?
Appendix D

Study participation informed consent form

Northeastern University, College of professional studies

Jeff Esposito

Navigating Open Innovation: An Exploration of High-Technology Engineering in Practice

Informed Consent to Participate in a Research Study

We invite you to take part in a research study. This form will tell you about the study, but the researcher, Jeff Esposito, will explain it in detail to you first. You may ask any questions that you have. When you’re ready to make a decision, please tell the researcher if you wish to participate or not. This is completely voluntary and you do not have to participate if you don’t want to. If you decide to participate, the researcher will ask you to sign a statement and will give you a copy to keep.

Why am I being asked to participate in this research study?

We are asking you to participate in the study because you are an engineer with experience practicing invention and development in a global technology firm.

Why is this research study being done?

The purpose of this study is to understand how engineers describe their own experiences trying to practice agile and profitable innovation in high-technology.

What will I be asked to do?

If you choose to take part in this study, we will ask you to participate in two 35 minute long interviews and to complete an inbound and outbound set of written questions. This interview will be conducted on either locally on premises or through teleconferencing and will be recorded using a digital recorder. Afterwards, the researcher will have the interview transcribed and will email you the transcription for your review corrections and any additional thoughts you would care to add.

How much of my time will study participation take?

Each of the two interviews will take roughly 35 minutes and each set of written questions should take under 10 minutes for each making an approximate total of an hour and 30 minutes of your time.
Will there be any risk or discomfort to me?

There is absolutely no foreseeable risk, impact or possibility of discomfort on any level from participating in the study. While there is always a possibility that interview data and related audio recordings might get lost or stolen, this would result in a small amount of risk based on the nature of interview questions. It is however, very unlikely as materials will be archived and encrypted after being professionally transcribed. In the highly unlikely event that study data is lost or stolen, the researcher will notify you immediately.

Will I benefit by being in this research?

There is no direct benefit to you for participating in the study. You may feel some indirect benefit from knowing that your participation and contribution in the study may lead to programs that ensure more effective and efficient processes in innovative work in the high-technology industry in general.

Who will see the information about me?

Beyond Jeff Esposito, your identity as a participant in the study will not be known to anyone. Your part and contribution in the study will be kept confidential and anonymous. Only the researcher, Jeff Esposito, will see the information about you. No reports or publications will use information that can identify you or compromise that anonymity in any way. Your statements during the interview will be transcribed by a professional company following industry best practices and standards for complete security and confidentiality. Participants are identified by pseudonyms, such as EngineerOne, EngineerTwo, EngineerThree, etc. all recordings and transcripts will be securely maintained by the researcher until the thesis has been fully approved. Afterwards, all transcripts, recordings, and data files will be securely wiped from all media and effectively destroyed.

Real names will not be used in any notes taken during the interviews. You will be assigned a pseudonym that only the researcher will know. That pseudonym will be used throughout the interview to ensure confidentiality can protect your identity.

Your responses to the written questions will be treated similarly to protect your anonymity and confidentiality.

While it is rare, authorized people with Northeastern University may request to see research information about you and other people in this study. This practice is performed only to ensure that the research is done properly. We would only permit people who are authorized by the Northeastern University institutional review board to see this information.

Can I stop my participation in this study?

Your participation in this research is completely voluntary. You do not have to participate if you do not want to, and you can refuse to answer any question you choose. Even if you begin the study, you can quit at any time. If you do not participate or if you decide to quit, your anonymity will not be compromised in any way. Immediate destruction and wipe of all materials for your participation would occur if you announced your desire to quit the study.
Who may I contact if I have questions, concerns, or problems?

Please contact the researcher, Jeff Esposito, at (401) 528-9771 or by email at esposito.j@husky.neu.edu. You may also contact the Principal Investigator, R.E.L. Brown, EdD by email at Ron.Brown1@northeastern.edu.

Who can I contact about my rights as a participant?

If you have any questions or concerns about your rights in this research, may contact Nan C. Regina, Director, Human Subject Research Protection, 960 Renaissance Park, Northeastern University, Boston, MA 02115. Telephone (617)373-4588, email: irb@neu.edu. You may call anonymously if you wish.

Yes, I agree to take part in this research:

___________________________________________________________________
Print Name/Signature/Date

___________________________________________________________________
Print Name/Signature of person who explained the study/Date
Appendix E

Correlation of Interview questions and Writing prompts to research questions

The focus of this research is to explore and understand how engineers describe their own experiences in practicing invention and development. The scope of exploration is one of social, cultural, organizational, and personal contexts throughout their careers. Thus, the primary research question and supporting sub questions as detailed in Chapter 1:

- **RPrime** How do high-technology engineers in a global firm describe their own experiences trying to practice agile and profitable invention and development?
  - **RP1** What are their positions on competitive advantage and open knowledge sharing as part of the open source technology trend in the industry?
  - **RS1** What are they experiencing for enablement of diverse perspectives as part of an inclusive and socially beneficial research focus?
  - **RP2** What insights can they share about professional, cultural, and organizational hurdles in the pursuit of profitable technical innovation?
  - **RP3** What kinds of unique challenges have they experienced creating cohesive, fully collaborative, and culturally respectful knowledge sharing partnerships?
  - **RP4** What are their feelings and perspectives on the role of high-technology as a means to create a just global society through shared knowledge?
  - **RS2** What aspects of their own innovation process would they want to preserve while working to achieve fully socially relevant and financially viable technical innovation?
Research questions were codified for easy mapping to interview questions and writing prompts, helping to ensure alignment of interviews to the overarching research question in the study. Clarity and methodological congruence is encouraged through this alignment and an example is provided in Table E1. This technique is an adaptation of software design principles that map functional specifications to the overarching requirements (Gamma et al., 2015).

Table E1 Question mapping towards research congruence

<table>
<thead>
<tr>
<th>Research Question to Interview Question Mapping - Interview 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Participant Meaning Making Category</strong></td>
</tr>
<tr>
<td>Speculate</td>
</tr>
<tr>
<td>Reflect</td>
</tr>
<tr>
<td>Prioritize</td>
</tr>
<tr>
<td>Assess</td>
</tr>
<tr>
<td>Considered, Lived Experiences and Problem Solving</td>
</tr>
<tr>
<td>Reflection across Personal Experience</td>
</tr>
<tr>
<td>Realization</td>
</tr>
<tr>
<td>Investment and Engaged Personal Synthesis as Opinion</td>
</tr>
<tr>
<td>Exploration</td>
</tr>
<tr>
<td>What IF stepping outside of personal experiences</td>
</tr>
<tr>
<td><strong>Research Question Alignment</strong></td>
</tr>
<tr>
<td>RP1</td>
</tr>
<tr>
<td>RP1</td>
</tr>
<tr>
<td>RP2</td>
</tr>
<tr>
<td>RP3</td>
</tr>
<tr>
<td>RS2</td>
</tr>
<tr>
<td>RP1/2</td>
</tr>
<tr>
<td>RP3/4</td>
</tr>
<tr>
<td>RP5</td>
</tr>
<tr>
<td><strong>Interview Question</strong></td>
</tr>
<tr>
<td>Alignment of experience to ideal</td>
</tr>
<tr>
<td>Positive aspects in practice approaches</td>
</tr>
<tr>
<td>Prioritized connections to current challenges/deficiencies</td>
</tr>
<tr>
<td>Rank challenges to open, inclusive collaboration</td>
</tr>
<tr>
<td>Personal evaluation index</td>
</tr>
<tr>
<td>Real-life challenges</td>
</tr>
<tr>
<td>Cross-working group knowledge exchange experience across career</td>
</tr>
<tr>
<td>Perspectives on practiced inclusion</td>
</tr>
<tr>
<td>Proactive inclusion of diverse perspectives</td>
</tr>
<tr>
<td>Valued and respected traits and qualities</td>
</tr>
<tr>
<td>Valued and respected traits and qualities - confirmation</td>
</tr>
<tr>
<td><strong>Primary high yield focus</strong></td>
</tr>
<tr>
<td>Rationale</td>
</tr>
<tr>
<td>Deepen</td>
</tr>
<tr>
<td>Affirmation</td>
</tr>
<tr>
<td>Assessment</td>
</tr>
<tr>
<td>Granularity</td>
</tr>
<tr>
<td>Completeness</td>
</tr>
<tr>
<td>Retrospective comparison</td>
</tr>
<tr>
<td><strong>First Cycle Coding by section</strong></td>
</tr>
<tr>
<td>In Vivo</td>
</tr>
<tr>
<td>Causation</td>
</tr>
<tr>
<td>Disabliged</td>
</tr>
<tr>
<td><strong>Emergent Themes</strong></td>
</tr>
<tr>
<td>In Vivo</td>
</tr>
<tr>
<td>In Vivo</td>
</tr>
<tr>
<td>In Vivo</td>
</tr>
</tbody>
</table>

High-yield questions differentiate significantly from open-ended questions in that they engage different patterns of meaning making by encouraging different types of participant reflection. Questions were clustered together within categories of speculation, prioritization, analysis, comparison, and evaluation/exploration (SPACE). Thus, sets of questions that engage
similar sets of analytical thinking skills help to evoke what Seidman refers to as authentic inner voice (Seidman, 2013).

Application of this structuring of the interview protocol and writing prompts was partially inspired by research into experience-based and situational structured interview questions (Pulakos & Schmitt, 1995). The approach is not perfect, but does help to triangulate on participant thought process preferences, helping to cue the researcher towards effective follow-up.

Tables E2 and E3 detail the categorized and mapped interview questions themselves. Table E4 details the categorized and mapped writing prompts. Here we can see probes, prompts, and follow-ups geared towards engaging the participant in further reflection and thought. The implicit value to the participant was the opportunity to examine and reflect on their own experiences, their own stories of invention and development in context of their own goals and ambitions. As always, we sought to cultivate what is of interest and doing it in an organized fashion can only enable deepened, accessible analysis.
Table E2 Interview question detailing for interview 1

<table>
<thead>
<tr>
<th>Participant Meaning Making Category</th>
<th>Research Question Alignment</th>
<th>IQ #</th>
<th>Primary High Yield</th>
<th>Follow-up detailing</th>
<th>Probes</th>
<th>Possible Dominant Coding stance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speculation</td>
<td>Speculate and Reflect</td>
<td>RP1</td>
<td>1</td>
<td>Reflect on your initial goals when you decided to pursue a career as an engineer; how does your current practice of technology development align with open source technology practices?</td>
<td>And why?</td>
<td>In Vivo</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RP1</td>
<td>2</td>
<td>What have you seen done particularly well and been a part of in your career that encourages openly shared development and innovation?</td>
<td>Interesting... please tell me more...</td>
<td></td>
</tr>
<tr>
<td>Prioritization</td>
<td></td>
<td>RP2</td>
<td>3</td>
<td>Think about past projects you’ve worked on, anywhere and anytime in your career. If you had to prioritize three things to correct around cultural and organizational hurdles to innovation, what would they be?</td>
<td>Valid points... anything else to add on that?</td>
<td>Causation</td>
</tr>
<tr>
<td>Rank, Order, and Assess</td>
<td></td>
<td>RP3</td>
<td>4</td>
<td>What would your rank as your key challenges in creating solid knowledge sharing partnerships and collaborations with others?</td>
<td>Interesting... why did you choose X as top rank?</td>
<td></td>
</tr>
<tr>
<td>Analysis</td>
<td></td>
<td>RS2</td>
<td>5</td>
<td>What aspects of inventing and developing have been especially fulfilling?</td>
<td>How important is social relevance in terms of profitable work for you?</td>
<td>Demonstrative</td>
</tr>
<tr>
<td>Considered, Lived Experiences and Problem Solving</td>
<td>RPPrime</td>
<td>RP4</td>
<td>7</td>
<td>Based on your own experiences and real-life practice, what do you see as the greatest challenge to collaborative new technology development?</td>
<td>Across the world? ... In online communities?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td>What comes to mind on the role of shared knowledge through high technology to make a more just and inclusive world?</td>
<td>How do you think that may change in the next 5-10 years?</td>
<td></td>
</tr>
<tr>
<td>Reflection across Personal Experience</td>
<td></td>
<td>RP3</td>
<td>8</td>
<td>When it comes to creating mutually respectful knowledge sharing relationships, what have been your experiences throughout your career?</td>
<td>Was it always that way? If not, what has changed for better or worse?</td>
<td>In Vivo</td>
</tr>
<tr>
<td>Evaluation</td>
<td></td>
<td></td>
<td>9</td>
<td>What is your opinion of how sincerely diversity is practiced in the high-technology industry in general?</td>
<td>Interesting... please tell me more...</td>
<td>In Vivo</td>
</tr>
<tr>
<td>Investment and Engaged Personal Synthesis as Opinion</td>
<td>RPPrime</td>
<td>RPPrime</td>
<td>10</td>
<td>What are your thoughts and experiences on including different professional perspectives early in product development?</td>
<td>Interesting...</td>
<td></td>
</tr>
<tr>
<td>Exploration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What IF Exploring the future based on past experience</td>
<td>RPPrime</td>
<td>11</td>
<td></td>
<td>What would you set as your own code of conduct/rules of the road to avoid pitfalls you’ve encountered in making agile innovation happen?</td>
<td>Interesting... why’d you choose (X) as an emphasis?</td>
<td>Emotion</td>
</tr>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

Why is that, do you think? How might you recreate that kind of satisfaction?
### Table E3: Interview question detailing for interview 2

<table>
<thead>
<tr>
<th>IQ to RQ Map for Interview 2</th>
<th>Research Question Alignment</th>
<th>IQ #</th>
<th>Primary high yield</th>
<th>Follow-up detailing</th>
<th>Probes</th>
<th>Possible Dominant coding stance</th>
<th>Member Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speculation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speculate and Reflect</td>
<td>RP1</td>
<td>1</td>
<td>Think about your career to date. What might you change anywhere in the entire invention and development cycle based on your experiences?</td>
<td>Then what?...</td>
<td></td>
<td>In Vivo</td>
<td></td>
</tr>
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<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RP1</td>
<td>2</td>
<td>What really stands out for you as key experiences that encouraged open innovation?</td>
<td>Interesting... please tell me more...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prioritization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rank, Order, and Assess</td>
<td>RP2</td>
<td>3</td>
<td>Thinking about your overall career experience, what has been particularly satisfying or frustrating when developing new technology?</td>
<td>Sure, OK... what about hurdles within the organisation itself?</td>
<td>Causation</td>
<td>Interview 1, question 4</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RP4</td>
<td>4</td>
<td>Based on what you’ve seen and done, what’s been among the most difficult aspects of building real partnerships and ongoing collaboration?</td>
<td>What came in second...?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Considered, lived Experiences and Problem Solving</td>
<td>RP4</td>
<td>5</td>
<td>What projects have you done along the way that either built up or broke down barriers to knowledge?</td>
<td>Anything you’d like to add to that thought?...</td>
<td></td>
<td>Enactuated</td>
<td>Interview 1, question 6</td>
</tr>
<tr>
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<td></td>
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<tr>
<td></td>
<td>RP4prime</td>
<td>6</td>
<td>What do you see as the single biggest hurdle to open technology research and development?</td>
<td>Throughout your entire career?</td>
<td></td>
<td></td>
<td>Interview 1, question 7</td>
</tr>
<tr>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RP4</td>
<td>7</td>
<td>Is an open and inclusive “global village” a myth? What have you experienced that makes you believe technology can make or prevent that from being a reality?</td>
<td>Will that always hold true, do you think?...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparison</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reflection across Personal Experience</td>
<td>RS1</td>
<td>8</td>
<td>What degree of diversity have you experienced in your practice of technical invention and development?</td>
<td>Tell me a story of your first experience of that...</td>
<td>In Vivo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment and Engaged Personal Synthesis as Opinion</td>
<td>RP2</td>
<td>9</td>
<td>How inclusive has your own engineering practice been?</td>
<td>OK... sure, has this always been the case?</td>
<td></td>
<td>In Vivo</td>
<td>Interview 1, question 9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rprime</td>
<td>10</td>
<td>What have been you seen and had to deal with yourself in navigating hurdles and roadblocks to move new ideas forward?</td>
<td>How do you feel about that...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exploration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What if? Exploring the future based on past experience</td>
<td>N/A - orienting</td>
<td>11</td>
<td>Let’s get in a time machine together, fast forward to five years from now. You can pick and choose any role as an Engineer. What would it be?</td>
<td>OK... have you hold that role in the past or is that something you’d like to explore?</td>
<td>Emotion</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RPrime</td>
<td>12</td>
<td>What if you could select among any engineers fresh out of college from anywhere in the world for a new team you were leading – what would you look for in them for traits and qualities, not necessarily professional skills?</td>
<td>Have all the teams you’ve either participated in or led possessed these traits and qualities? To what extent?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table E4 *Writing prompt detailing for inbound and outbound participants*

<table>
<thead>
<tr>
<th>Context</th>
<th>Research Question Alignment</th>
<th>#</th>
<th>Prompt</th>
<th>Follow up</th>
<th>Possible Dominant coding stance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inbound Participant</strong></td>
<td>RP2</td>
<td>1</td>
<td>What kinds of invention and development work have you been involved in for the most part throughout your career?</td>
<td>What has been the most enjoyable?</td>
<td>In Vivo</td>
</tr>
<tr>
<td></td>
<td>N/A - orienting</td>
<td>2</td>
<td>Looking back on it, does it seem a clear and direct path or were there turns and detours along the way, directions in your journey that you hadn't anticipated?</td>
<td>What has surprised you along the way?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rprime</td>
<td>3</td>
<td>Describe your favorite invention and development experience</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Outbound Participant</strong></td>
<td>RP1</td>
<td>1</td>
<td>Where do you see your passion for technological invention taking you next?</td>
<td>What projects are you looking forward to getting involved in?</td>
<td>Emotion</td>
</tr>
<tr>
<td></td>
<td>Rprime</td>
<td>2</td>
<td>Describe an ideal development project. One that of course is profitable, but also one that you would find very fulfilling as well.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RS2</td>
<td>3</td>
<td>What kinds of advice on technology development would you give your younger self if you had the opportunity?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix F

Procedural synopsis of study data collection

Semi-automated interview transcription

Baker’s (2015) use of semi-automated voice recording and transcription describes an efficient and ethical handling of participant data (Baker, 2015). Rev (@https://www.rev.com/voicerecorder) is both an iPhone app and a web-based service company that offers transcription, captions, subtitles, and translation services on a per minute fee structure. In pre-study field testing transcripts took anywhere from 12 to 24 hours to be transcribed and when checked against original test recordings and field notes, were sufficiently accurate.

Figure F1 shows the three steps involved in interview recording and transcription. Note that unless speaker names are explicitly added, the transcription is produced with “speaker 1” and “speaker 2” as the default assignments. This aligns with the intent to guarantee participant confidentiality.

Figure F1. Semi-automated interview transcription.
Recording redundancy

To protect participant’s investment of time, interviews were recorded simultaneously with a secondary digital recorder. The intention was to have two completely similar recordings made at the same time of the interview in case one of the recording devices failed. Because of the capacity of the Rev Web service, interview recordings as mp4 files were able to be uploaded from either digital recording source.

Data collection and curation tracking

Table F1 describes data collection and curation tracking by participant. The intent is to ensure consistent attention to ethical handling of the data and as a means of keeping essential validity checks such as member checking on track within the study. This also provides an auditable trail of data curation.

Table F1 *Tracking data collection and curation by participant*

<table>
<thead>
<tr>
<th>Task</th>
<th>Date complete</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Obtain Consent form</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Inbound writing prompt encrypted and archived</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Interview 1 transcribed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Interview 1 transcript verified, encrypted and archived</td>
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<td>5 Interview 2 transcribed</td>
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<td>6 Interview 2 transcript verified, encrypted and archived</td>
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<td>7 Interview transcripts sent to member</td>
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<td>8 Member check complete</td>
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<tr>
<td>9 Outbound writing prompt encrypted and archived</td>
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<td>10 Planned Data destruction date</td>
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Encryption and archival

Appropriate curation of the recorded interviews consisted of transferring them off the recording device into a password-protected device as both backup and secure storage. Archive of the curated data was on a secure SSD drive that is encrypted using the established AES algorithm, and removal/wipe of unprotected files from both recording devices will be performed on completion of that archival process. AES is in use by the US government to protect digital information at the file level up to top secret classification.

Secondary data collection in the form of writing prompts for participants was subjected to the same curation discipline. Writing prompts were marked confidential and private within email and directed solely to an appropriate university email address. The results of the prompts will be archived and curated with the same procedure as the primary data.