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The Love of Inventing, from Veblen to Amabile: A Look at the Construct "Inventor/Innovator" from the Era of Edison to Today's Corporate R&D Scientist

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Abstract

Large firms, having a desire to achieve disruptive innovation, will need to rely on the inventive, innovative, and entrepreneurial spirit of the "hired" inventors they employ to do such work. This report traces the roots of the theories of motivation concerning the construct "inventor/innovator" from the time of the heroic individual inventor in the late 1800s until today, within the context of the evolution of the corporate R&D institution. Understanding the motivations and characteristics of the early "heroic" individual inventor as well as the evolving theory of appropriate R&D management strategy in large firms might chart a path to creating a better corporate environment for radical innovation (and better results). Characteristics observed over one hundred years ago align well with the current theories of the best way to enhance corporate employee creativity, leading to higher innovation rates, what Veblen called "the instinct of workmanship" parallels closely to what Amabile defines as "intrinsic motivation".

Keywords: Inventor; Innovator; Management; Entrepreneurial; R&D scientist; Workmanship

Introduction

Ongoing academic research has reinforced the importance of the contribution of certain individuals in efforts to drive radical innovation programs to successful outcomes in large firms [1]. As large companies have up-levelled the priority of radical innovation objectives, in order to help insure their own long term sustainability, scholars such as Theresa Amiable have suggested that within a component framework there is an optimum balance of intrinsic and extrinsic motivation which will lead present day corporate inventors and innovators to higher levels of success. She concludes that motivation coming from within is the most powerful [2]. Her work supports the importance of finding and retaining highly creative/inventive staff in 21st century R&D organizations.

In Leifer's 2000 publication, Radical Innovation, How Mature Companies Can Outsmart Upstarts, three key roles are identified which, collectively, drive radical innovation programs. They are described as "Creative Technologists," "Entrepreneurial Managers," and "Visionary Champions." The authors Leifer et al. [1] after completing an extensive investigation into the topic, observed the following: "We were surprised by the lack of corporate attention paid to the critical roles played by these individuals in the success of radical innovation projects" [1].

The observation above, concerning the relationship between the firm and these individuals, forms the basis for this report. While this review of theory and constructs will fall far short of providing any prescription to firms looking to cultivate inventors/innovators, there are several underlying questions that should be visited, at least indirectly. In 2007 (present time), do large firms generally yet have a clear and proven idea of what an innovative employee looks like from the standpoint of job characteristics or other predictors? Could a firm identify within its employee pool today, given its current understanding of the construct "inventor/innovator", which the best person would be to assign to the innovation task (especially if the desired innovation is radical or disruptive)? Is there any validity to the idea that inventor/innovators look like the "reclusive scientist" or "spaced out nerd" or any other stereotype? How do potentially hidden present day "Edison's" cope within the corporate research and development institution given the structure and management theories currently invoked? How does the effort to move further and further towards routinization in large firms (SAP, Customer Relations Management, Stage gate) affect these individuals and their potential for long-term career success? Can firms effectively harness the value creation potential from these innovators?

This investigation attempts to trace the evolution of the construct "inventor/innovator" within the context of the large firm from just prior to the time that the first corporate research and development (R&D) organizations emerged (in the late 1800s) until the present. Increased emphasis has been placed on the earlier years in order to carefully revisit potentially lost or overlooked knowledge as a result of emergence of strong stereotypical imagery related to the identity of the "hired" inventor/innovator in those early years which may still carry through until today. That stereotype defined more clearly is the image of the white coated, intelligent, analytical, reserved, research scientist toiling away in a multimillion-dollar research lab from eight to five each workday. One might ask if the first research directors did a good job of preserving the inventive/innovative behavior when they first began to bring inventors inside the firm in the late 1800s. Was their hiring profile correct? In addition, in order to better understand the environmental changes, which have impacted the innovator, a parallel look at how the theory of management of these individuals within the confines of corporate R&D organizations has changed during the same period is also attempted. It is clear that when looking at the

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historical perception of the innovator, there might be an interesting and fundamental de-linkage between the psychological orientation of the early innovator not affiliated with the corporate infrastructure and the "hired" innovator who resides within the confines of a firm's R&D wing. In other words, would a Fortune 500 firm want to hire or be able to retain innovative employees in large numbers if they all behaved like Thomas Edison?

It is hoped that through better understanding of the construct "inventor/innovator" that theories will arise that optimize the performance of the "hired" inventor/innovator in the corporate environment and also ideas will emerge as to how large firms might optimally treat these individuals. If successful in achieving these goals, then large firms might have better luck in generating disruptive technology on a more repeatable basis.

Academic investigation starting with the earliest days of R&D organizations until today indicates that innovation activity in large firms has not been an easy task to accomplish in that, even in recent times, most true innovation still occurs outside of the large firm. For example, in EricVon Hippel's investigations, which formed the basis for the lead user concept, he was surprised to find that users (not corporate R&D actions) were found to be the actual developers of 82% of all commercialized scientific instruments studied and 63% of all semiconductor and electronic subassembly manufacturing equipment innovations studied [3]. It is also interesting that many of the most progressive large firms of today are looking outside for innovation. Currently, "Open Innovation," is a growing concept, which was originally promoted by Henry Chesbrough, a professor and executive director at the Center for Open Innovation at Berkeley [4]. The central idea behind open innovation is that in a world of widely distributed knowledge, companies cannot afford to rely entirely on their own research, but should instead buy or license processes or inventions (i.e., patents) from other companies or individuals. Could open innovation be an attempt on the part of large firms to find a conduit to the heroic inventor(s) living in the present timescape?

This literature review will investigate the theoretical roots of the construct "inventor/innovator" in the context of organized corporate research and development organizations, with special emphasis on the evolution of the ideological views held by firms concerning strategic management of these resources. It is also interesting that based on the mention of the three roles by Leifer et al. [1] that it is possible that in the modern firm the construct "inventor/innovator" has experienced a certain level of "Taylorism" where the original holistic descriptor has now evolved into three (or possibly more) component activities (visionary, entrepreneur, and creative technologist) which most likely are performed by three different individuals or groups of individuals. In addition, within each role, systematic processes such as stage gate have been implemented which may further chip away at the underlying inventive behaviour [5]. Although each of the component parts are of eventual interest, it is important to isolate the "creative technologist" mentioned by Leifer for the purposes of this discussion. Therefore this report will follow the trail of the construct inventor/innovator in the late 1800s to the current day creative technologist or radical innovation inventor role. As a starting point it is important to differentiate the terms "invention" and "innovation." In some cases it is acceptable to use these terms interchangeably but in other cases it is not. The appropriateness of interchange is dictated by their individual definitions.

Invention versus innovation

"An important distinction is normally made between invention and innovation. Invention is the first occurrence of an idea for a new product or process, while innovation is the first attempt to carry it out into practice" [6]. The latter definition is important in our delineation of the construct. It is clear that an innovator fundamentally differs from an inventor because he or she (innovator) is focused on a point in the process that is chronologically after the idea generation or initial creative discovery stage and is more aimed at making first use of the idea, which is in most cases, for the benefit of society or for commercial interest. It is possible that an innovator will recognize linkages between several inventions which then will result in the true innovative result. It is also important for the innovator to be able to understand the nuances of the environment in which the invention might impact. It is clear that in both the case of the inventor and innovator, the individual or group of individuals must be creative. Creativity is an especially important trait that is underlying in the action of inventors and innovators. It might be said that an inventor is free to be creative for the pure sake of personal interest while and innovator is creative and at the same time must take into account the relevance of his or her creation in society.

For completeness, it is also important to point out that while an innovator is, given some level of risk and commercial objective, in virtually all cases, exhibiting a form of entrepreneurial behavior, an entrepreneur on the other hand does not necessarily have to be an innovator. For example, an entrepreneur who is not an innovator could simply observe an innovator at work and then can follow quickly to copy the innovator's output based simply on some level of risk/return estimate (further definition of the term entrepreneur, although important to the topic being discussed, is beyond the scope of this report).

Key differences between these actors, (inventor versus innovator versus entrepreneur) notwithstanding, in many cases, given the right environment, the creative technologist of today will assume the role of inventor, innovator and to some extent entrepreneur in the context of the large organization. Therefore, in this report, given the understanding of the key differences in the constructs, the terms; inventor, innovator and entrepreneur can often be used interchangeably, with great care, of course.

One of the more famous examples of the differences, as well as the overlap, between inventor, innovator and entrepreneur is the case of Guglielmo Marconi reported by Rupert MacLauren [7]. Marconi was neither a brilliant nor a highly trained scientist. Having an interest in physics and chemistry, Marconi, at age 20, read an article about the work and experiments of Hertz which impacted him a great deal. As a result of his reading, Marconi's imagination was stirred by the possibility of making wireless communication a practical reality. Since Marconi was from a wealthy background he did not have to worry about making a living and had the time to focus on the narrow stream of research in this field and also was able to use family connections to capture backing for his commercial pursuit. Marconi first compiled a working knowledge of the present state of the art inventions (created by others) for which he would perform experiments around in order to make these presently "imperfected", unrelated but in fact interconnected contrivances practical. Marconi's clear focus was on innovation. Years before this, Benjamin Franklin was quoted as follows: "I have always thought that a man of (only) tolerable abilities may work great changes, and accomplish great affairs among mankind, if he first forms a good plan, and, cutting off all amusements that would divert his attention, makes the execution of the that same plan his sole study and business." Franklin's quote describes Marconi as well as many other innovators. In the case of Marconi, his persistent innovational activity along with the

environment of his age and to some extent luck parlayed his obsessed behavior into a large sum of money and fame as an "entrepreneur" … but it is unclear, since he was already wealthy, if the financial driver was really very important to his innovative activities. Actually from the standpoint of his entrepreneurial success, he narrowly escaped bankruptcy if not for the "lucky" timing of a ship sinking which made his innovative ship to shore communication method in high demand [7].

Let's look at the definition of economic innovation to add some depth to the construct.

Joseph Schumpeter helped to clarify the understanding of the role of innovation from the standpoint of economic theory. Schumpeter defined economic innovation: [8]:

1. The introduction of a new good —that is one with which consumers are not yet familiar—or of a new quality of a good.
2. The introduction of a new method of production, which need by no means be founded upon a discovery scientifically new, and can also exist in a new way of handling a commodity commercially.
3. The opening of a new market, that is a market into which the particular branch of manufacture of the country in question has not previously entered, whether or not this market has existed before.
4. The conquest of a new source of supply of raw materials or half-manufactured goods, again irrespective of whether this source already exists or whether it has first to be created.
5. The carrying out of the new organization of any industry, like the creation of a monopoly position (for example through trustification) or the breaking up of a monopoly position.

Using Schumpeter's definition for economic innovation, the inventor will take the position of generating an idea which impacts one or more of the five items listed above, while the innovator (or even more broadly the entrepreneur) will take action to move the idea into commercial practice. Schumpeter used the phrase "creative destruction" to describe the action taken by entrepreneurs to kill the old and replace it with new in terms of how innovation takes it shape: "a process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one". Creative Destruction is very close in concept to the more widely discussed concepts today of radical or more precisely disruptive innovation [8].

Clayton Christensen, business professor at Harvard recently described how existing incumbent firms have a hard time dealing with creative destruction from both observed external competitive threat and at the same time surprisingly even when the ideas for disruption comes from within [9].

"It's become quite clear to me that the existing business units that sell the existing products made from existing technology find it difficult to go after disruptions. First, because the economic model is unattractive, but secondly, the existing business generally is still very strong when the disruption emerges. In addition, for them to try to change the way they go about their work, to go after the disruption, means that they have to walk away from very profitable products and customers".

Christenson's observation, that the tendency of the large incumbent firm to shun a destructive enhancement, may provide some insight as to why an innovator for hire might find it difficult to fully integrate his or her efforts effectively into a large firm. Christenson has concluded that because of the many costs (both financial and non-financial) to the firm and its management associated with the "creative destruction" process; firms are very slow to accelerate actions to drive change. There is just too much inertia in place to keep on doing the same thing that has always done. The concept of "kill the messenger" might be at play without it even being recognized. The "hired" innovator might find the inertia of the firm to maintain existing structure a point of frustration and conflict. Let's now examine the historical evolution of thoughts and understanding relative to the construct "innovator," again keeping in mind the earliest innovators often also assumed the role inventor and entrepreneur.

Construct--creative technologists–inventors/innovators

Thorstein Veblen, a noted economist, often credited as being one of the founders of the institutional and evolutionary economics movement, pointed out prior to his publication in 1914 that mankind is endowed with a native "aversion to futility," a "propensity to useful effort," or an "instinct of workmanship," and that the "aversion to labor," which economists have been wont to regard as a primordial trait of human nature, is in fact a by-product of that institutional development which has created private property and a conspicuously leisured class [10,11]. Veblen's instinctual theory was aimed at challenging the economic principle that an economic agent, given the option, will prefer leisure time to work. Veblen pointed out that natural survival instincts come into play and that it is intuitively obvious that an organism, which did nothing productive, would be in conflict with the natural scheme. In fact, the interesting conclusion that might be drawn is that certain individuals (if not all) actually gain utility through the act of invention/innovation similar to the artist or musician who simply enjoys his or her work for its own sake versus sitting in a quiet room. Prior to Veblen's observation, the contemporary community of economists classified all work and being utility reducing and therefore in order to achieve iso-utility some compensation would be required for the worker.

Frank W Taussig, a respected Economics professor at Harvard University, took Veblen's assertion a step further when in 1914, he augmented Veblen's instinct argument, by tying it to William MacDougall's earlier work, attempted to completely disprove the common belief that in most cases "necessity was the mother of invention" when he reinforced MacDougall's theory of "the instinct of contrivance" [12]. Like Veblen, MacDougall, believed that unlike earlier economists such as J S Mills, that man was not inherently lazy (seeking leisure), but had an inherent desire to create. Each individual possessed to a varying degree an instinctual need to create some sort of productive output. The inventor/innovator simply had a greater propensity when it came to this instinct as compared to the general population, similar to how a beaver in nature might have a greater instinct to contrive than a lion [13].

But according to Waldermar Kaempffert, science historian of the early 1900s, how the instinct of contrivance shall manifest itself is determined by the social and economic pressure of the time. He postulated that there might be instincts at play but the environment or historical era also had a great influence on the inventor. In this respect, invention is like art. Jazz and futuristic painting could not have appeared in Lorenzo di Medici's time, nor could the dynamo and radio, simply because the proper cultural and technical heritage were lacking. This means that while "Edison's" happen as do "Michelangelos" they are stimulated by the artificial environment that their predecessors have

created. Some would say that the heroic inventor exclaiming "eureka" is simply the fortunate sole who is the last one in the continuum of effort who after all the accumulated knowledge has been gathered (by the historical work of others) is the lucky one at the end who achieves the fame [14].

By the early 1920's, theories that involved natural instinct came under a great deal of attack, almost a revolt. Psychological instinct theory was questioned because it appeared at the time to be unscientific and "metaphysical," at the same time the views of Veblen and others were also pulled into the emerging nature versus nurture debate [15].

In 1922, Frank H Knight noted: "If instincts are to be scientifically useful, it must be surely possible to get some idea of their number and identity, but there has always been substantially unanimous disagreement on this point. Logically the choice seems to lie between meaningless single instinct to do things-in-general and the equally meaningless hypothesis of the separate instinct for every possible act". Knight also attacked instinct theory on the basis that it ignored environmental, cultural, and social factors [15]. The ensuing controversy caused many academics at the time to move from an instinctual pretext in devising theory to more of an orientation toward objective behavioral approaches. The more empirical approach was much less controversial, since principal investigators simply observed and reported behavior, while (often in the background) still taking into accounts the intangible instincts as "guiding principles". The behavioral approach formed the basis for the field of industrial psychology and also provides a pathway toward deeper behavioral economic theory. Before leaving the topic of instinctual psychology, a quote from Ordway Tead concerning innovation in 1919 might be appropriate. Tead was a noted educator, author and civil libertarian, who are often cited as being one of the first to recognize the value of employee empowerment.

"(Instinctive) Delight in creation and a sense of proprietorship over things created offered an explanation for the genesis of most industrial innovations. Their suppression is a prerequisite of industrial stagnation and social revolt". Tead goes on to criticize scientific management and Taylorism in this context, "In a corporate society based in the excessive subdivision of productive tasks, all instincts of creative planning are taken away from the workers, and each operation becomes meaningless with no craftsmanship or joy" [15].

Taussig who was perceived as being a more orthodox economist as compared to those who espoused instinct theory walked a thin line when he used data to strengthen his view on the instinct of contrivance when he profiled many important inventors in the 19th century from Seimens to Edison [12]. Through his investigation, he developed theories as to the psychology of the inventor/innovator. He like Veblen and McDougall proposed from a purely economic perspective that most inventors did enjoy increased utility as a result of the inventive activity. Instead of relying on purely the theory of instinct, he simply observed this based on a review of biographies of great inventors. Counter to the premise that work is inherently a utility reducer. He noted that regardless of personal wealth (or even lack thereof), the inventors in his time just kept on inventing (and innovating). In fact, many of the inventors, although well known for their more famous inventions each were involved in many more innovations /contrivances of lesser importance or even of famous but interesting inventive failures. Even Edison, holder of over 1000 patents had some noteworthy innovation related failures, which were often very costly to his personal wealth. The greatest failure of Thomas Edison's career was his inability to create a practical way to mine iron ore. He worked on mining methods through the late 1880s and early 1890s to supply the Pennsylvania steel mills' demand for iron ore. In order to finance this work, he sold all of his stock in General Electric (proceeds from earlier electrical innovations), but was never able to create a separator that could extract iron from unusable, low-grade ores. Eventually, Edison gave up on the idea, but by then he had lost all the money he'd invested. Edison therefore lost over $4 million (in 1890's dollars!) based on the prior sale of his GE stock at the time and when asked about it he said, "Well it's all gone but we had a hell of a good time spending it!". This example also shows that inventors such as Edison single-mindedly moved from the inventive process (idea generation) to the innovation steps (taking to practice) [16]. Like many inventors/innovators, the good time had by Edison has something to do with being "in the groove" while immersing oneself in the individual's process of innovation.

Kaempffert's analogy to the inventor/innovator being like a jazz musician may be even more appropriate than implied by his original connotation which was in the context of environmental drivers. More recent studies have shown that when both inventors and musicians/artists are involved in their most creative of activities they (artist, innovator) are both in much the same mental state (sometimes referred to as being in "the Zone"). "Flow" is the mental state of operation in which the person is fully immersed in what he or she is doing, characterized by a feeling of energized focus, full involvement, and success in the process of the activity. Proposed by psychologist Mihaly Csikszentmihalyi, in the 1990s, the concept has been widely referenced across a variety of fields [17]. Flow might explain the stereotypical absent minded professor who is so immersed in inventive activity that he or she is oblivious to the more mundane external world. It is of interest that it is only since the advent of the hired inventor in the corporate R&D lab has the imagery of the popular contrast between technologist and artist has been portrayed. In most corporate cultures, the technical people are assumed to be very different in characteristics than the artist or "undisciplined" creative functions. In fact, most technical people tend to discount the "artsy" types. The current corporate hired inventor can often be described as highly logical, "left brained" analytical "knowledge worker" while the artist is often described as creative, "right brained" individualist [18]. Based on the early days of the great inventor it appears that this degree of separation was not always the norm. In fact, it may be that the current perception of the hired inventor is a product of the corporate institution that might de-select the inventor artist in favor of a more linear thinking scientist. Could this be the case? If so, does this explain the lack of disruptive innovation as compared to the prolific output of the incremental improvements associated with more linear thinking?

In fact, many biographies of the most famous inventors have shown that a surprisingly large proportion of these change agents had a strong propensity for the arts as well. Could it be that truly creative innovators and artists are in fact "wired" the same way and not in opposition as portrayed more recently in the 1900s? For example, Robert Fulton, the man credited with the invention of the steamboat was also renowned portrait artist [19].

Daniel Pink [18] seems to challenge the current wisdom that defines the "hired" inventor/innovator as an analytical thinking, left brained technologist. Pink has proposed that while the last several decades have seen the rise of the knowledge workers (engineers, scientists, even MBAs) who can apply learned skills in an organized fashion to achieve incremental gains, the future will see an emergence of "right brained" creators, empathizers, pattern recognizers and meaning makers. These people – artists, inventors, designers, storytellers, big picture thinkers – will now reap society's richest rewards and share its greatest joys

[18]. Pink's "new age" prediction seems to sound an awful lot like Frank Taussig dissertation outlined previously and, of course, Taussig discussed this topic over 100 years earlier. We will see in the latter sections this report that the research directors of the earliest R&D labs might be responsible for shifting the innovator paradigm of the creative right brained individual inventor to the left brained hired technocrat.

Joseph Rossman, a researcher in the late 1920s and early 1930s, investigated the psychological aspects of the "great heroic" turn of the century inventor/innovator/entrepreneur using survey methodology [20]. Rossman had training as a chemical engineer, was a lawyer, and had a doctorate in psychology, so he had a unique set of interpretive skills when it came to understanding the persona of the inventor/innovator.

He conducted important field studies which helped to profile the individual inventor/innovator [20]. He was able to use survey methodology to directly obtain information from the virtual "who's who" of early twentieth century inventors (over 700 participated). He also surveyed a large population of patent attorneys who on an everyday basis worked closely with these individual inventors. He also surveyed 78 of the top research directors of large firms to understand their perception. These surveys are of interest since they might serve as a benchmark from the standpoint of contrasting the "hired" inventors/innovators in large firms today to the progenitor "great inventor" of pre-corporate time, since these individual innovators, in most cases, where doing their innovation before the R&D corporate umbrella was established. These pre-corporate R&D individual inventors/innovators were not biased by the corporate institution. Most of the inventors surveyed fell into the class of inventor who was also an innovator and entrepreneur.

Rossman's surveys of 710 famous inventors, who averaged 39.3 patents each, yielded some interesting (self-reported) results, which were substantiated by the collection of follow up data from the pool of patent attorneys, often times familiar with the inventors surveyed. The survey data was used by Rossman to construct a theory as to the profile of the inventive persona. For example, when asked what primarily motivated these inventors to invent, more than 27% replied that it was strictly due to "love of inventing", this was followed closely by 26.6% driven by a desire to improve the current conditions they observed and in third place at 23.5% was financial gain. Lower ranking responses were; 16.7% by strict "necessity" and remaining items at ~10 or less were; desire to achieve (10%), part of work (8%), prestige (4%), altruistic reasons (3%), laziness (1%), no answers (5%) [20].

In terms of the defining characteristics of a successful inventor, the following is a summary of the items provided by the survey of the successful inventors themselves; the top characteristic mentioned was "perseverance" at 70.8% (supporting the Edison view point) while number two was "imagination" at 29.5%. Analytical ability was ranked a distant seventh at 15.9% of surveys. Rossman sent the same survey to 78 "directors of research" at the larger firms operating the early R&D labs at the time (DuPont, RCA, GM, GE, etc.) and they ranked analytical ability highest at 61.5%. While perseverance and imagination still are ranked highly (~50% each), characteristics such as "training and education", reasoning and intelligence, and also "competence" show up on the research directors' rankings whereas they did not surface at all on the inventors ranking. It seems that if the research directors were representing the corporate view they might have made a great leap in the perception of effective inventors in the corporate context. The paradigm shifted quite dramatically based on the results of the survey. (From persistent and imaginative to analytical, intelligent, and competent).

Rossman [20] using his data (disregarding for the most part, the research directors) made the following postulate which extended the support of the inventor possessing a stronger "instinct of contrivance" or at least a stronger behavioral orientation attributed to inventors suggested by Taussig [12]: (it is clear that Rossman's conclusion in the paragraph below is linking the two primary motives – love of inventing and seeing a place to make an improvement as well as the drive, imagination and persistence they themselves mention).

"Although the inventor may not be driven by the so called instinct of contrivance in the psychological or biological sense, there is no question that he is impelled by a powerful bent or disposition to contrive, which for the purpose of the social and economic student, acts like an instinct. Inventors (innovators) differ from non-inventors (non innovators) not on account of any peculiar characteristics, but merely in the nature of their psychological reaction to deficiencies in man's handiwork. The tendency of the non-inventor is to 'cuss' deficiencies in his environment, whereas, the bent of the inventor is constructive criticism. He is characterized by the 'this-is-the-way-to-do-it' attitude. One of the important characteristics of the inventor is his ability to recognize industrial problems and needs and the possession of native ingenuity in utilizing his bag of tricks in contriving something to satisfy these needs".

One might challenge the surveys issued by Rossman [20] in that he might have issued those same surveys to people who were from the general population in order to gain higher inference. On the other hand, the rankings within this population are of great interest nonetheless. His findings that the research directors and the inventors had differing views of the key characteristics of inventors might be quite telling as the advent of corporate R&D management theory progressed, again at this point in history, the corporation seems to have rejected the inventive persona attributed to the famous case studies in favor of their own brand of hired inventor.

One last topic on the observational aspects of the early inventor has to do with business acumen. Whether it is through the eyes of Taussig, or Rossman or even the inventors themselves, they all had views concerning this topic. One paradox uncovered by Rossman was concerning business ability of the inventive personality. Roughly 23% of the inventors believed that business ability was a key characteristic of the successful inventor, (77% of the successful inventors themselves did not list this as a key characteristic and none of the research directors believe that this characteristic was important) but 15% patent lawyers actually indicated that the LACK of business acumen was a key characteristic of the great inventors. Many of the externally viewed motivators of invention are based on the financial, business rewards, which as a result of the inventor as a result of his or her work might achieve. From direct short-term financial gain to the long-term financial stability of an issued patent, the true action and motivation of the inventors seemed to conflict with conventional wisdom which implies money is a reward. Again very little evidence existed that conflicted with the theory that the inventor's innate desire to invent was its own reward and nothing further was required.

Taussig [12] theorized that patent law in terms of the individual inventor might have been an unnecessary measure since the inventive personality invented with or without financial reward. Although it should be acknowledged that the patent incentive it also in place for the backers of the inventor class and might be considered as more of a means than that of an end for most inventors. In addition Taussig learned that most (not all) financially successful inventors were teamed with smart business managers [12]. Otherwise they (the inventor) often

lacked the ability to focus on the returns. Could this be explained by the later Csikszentmihalyi theory of flow? Once the inventor is in the creative zone, might he or she forget or not care about the other less interesting aspects of the innovation such as the financial reward?

There are actually many amusing often quoted, often embellished, stories about the business acumen of inventors and innovators. Again, Thomas Edison takes the brunt of many published stories. For example, it was reported that Edison accepted and offer of 30,000 for the rights to one of his inventions only to learn later that the 30,000 was in British Pounds not US dollars. It was reported that unlike several other great inventors of the period, Edison did not have the trust in others to take on a business partner [16]. On the other hand, many great inventors benefited greatly by teaming up with a business partner who attended to the less creative but financially rewarding activities. The classic example of the innovation team is James Watt, inventor of the steam engine, and his business partner Matthew Boulton [21]. Boulton was an expert in both business concerns and also in manufacturing which was the perfect balance for Watt's creativity. Actually in the case of the Watt – Boulton pairing, in many cases the more interesting character of the two is in fact Boulton. It has been reported that while the inventor possesses a combination of unique characteristics, the business manager teamed with the inventive personality must not only possess strong commercial skills but also must have the psychological makeup to deal effectively with idiosyncratic behavior exhibited by the creative inventor. Is it possible that in today's large firms, that even if the firm is able to isolate the innovative/inventive agents, that unless the organization properly teams these individuals with the right "entrepreneurial" business managers the results will not be achieved? More recently it has been often observed that a technologist and business manager started some of the great companies of the high tech era. This topic deserves further follow up and although highly relevant is beyond the scope of this report. The following is one last word on the motivation of the early innovative personality:

Sir Josiah Stamp in his essay on Invention (Watt Anniversary Lecture, Greenock, 1928, reprinted in Some Economic Factors in Modern Life) inclines to the view that the flow of invention is largely explained in this way. "The inventor," he says, "is still ***sui generis,*** (unique in characteristics) and emerges from the ranks of engineers, physicists, and chemists, not indeed as a sport," but as a special product, which is touched by no economic spring". The sense of curiosity and the idea of fame play a greater part than the economic reward". Not all of the inventors, however, whose output is involuntary, are impervious to prospects of gain. Like artists, some may turn their talent to profitable use [22].

Progression of corporate research and development (and how this changes the construct "inventor/innovator)

As discussed previously, prior to the emergence of large organized firms and their corporate research laboratories in the early 20th century, which are now so common in today's business terrain, individual inventors and entrepreneurs were the driving force for innovation. As they say, life was simple back then, often artisans, craftsman or tinkers, were able to discover a new useful product and then somehow find a way to sell their discovery to the larger audience without the bureaucracy of the large firm. The actions of the "snake oil" salesman are not far from depiction of the actual output of the early industrial innovation process of the early to mid 1800s.

The individual inventor was the driving force for innovation at the turn of the century (1800s to 1900s) [23]. In 1901, 81% of U.S. patents were awarded to independent inventors, that is, inventors who were self-employed or employed in a job other than that of "hired" inventor [24]. It was the high point of the era of the independent inventor / innovator. It was the golden age. Thomas Hughes (scholar, University of Penn) dates its beginning to Bell's invention of the telephone and Edison's opening of the Menlo Park laboratory in 1876 and sees it ending at the time of World War I. The list of successful independents and their inventions from this period is impressive: it includes Bell's telephone; Edison's incandescent lamp, phonograph, and movie equipment; Stanley, Tesla, and Thomson's development of electric power systems; the Wright brothers' development of the airplane; and Fessenden and de Forest's pioneering in wireless. A large majority of inventors at the time were not trained scientists and many did not have more than one patent. There was an informal infrastructure in society that had a place for amateur inventors. The list includes professionals such as Edison as well as amateurs such as Bell and the Wrights [23].

Initial corporate research and development strategy can be traced back to the late 1800s and this endeavor (over time) created a significant shift of the focus of invention/innovation away from the individual heroic inventor to the hired R&D scientist as an inventive resource at home in the industrial corporation.

In the US, there was a realization at that end of the Civil War, that one of the key factors that lead to the north's victory over the south was the north's relatively superior technical know-how and industrialization at the time [25]. Many budding entrepreneurs and business leaders at the time connected the dots based on what they observed during the war and understood that technology advantage created an opportunity for substantial profits. While the war might have accelerated the understanding of the benefit of innovation, the initial stages of the industrial revolution probably made technology investment a necessity for larger firms as they strived to survive versus new entrants. Without some sort of organized investment in new product development or research, established companies would be potentially exposed to new inventions which primarily would come from the classic single individual inventor or upstarts and result in a great deal of economic disruption.

In 1867, the first corporate research and development (R&D) organization was established by BASF, in Germany, to develop dye formulations. In 1876, Thomas Edison established the original prototype corporate R&D lab in the US at Menlo Park. By the early 1900s several of the largest US companies, at the time, had followed Edison's model (e.g. GE in 1900, Bell Telephone in 1911, and Kodak in 1913). Edison's model is commonly referred to as the "First Generation" corporate R&D model [25].

It is difficult to say exactly what motivated Edison and those who followed to believe that a corporate inventive institution would effectively replace the more grass roots individual inventor as the primary driver of innovation. Edison, a "super contriver," might have just wanted to create a larger infrastructure to simply explore his own ideas. It was widely known that Edison considered "wooly haired" scientists as being to detached from reality to be of much help [16]. As far as systematic organization of labor, Edison (like other stereotypical inventors) was not often considered to be very patient. He once said to his team: Hell, there are no rules here - we're trying to accomplish something! To the organizational followers, the reason might have been less clear. They might have followed Edison, a successful innovator, on a certain level based on blind faith at first since if he was doing this in this fashion then this might be the way to systematically replicate his inventive success. But one might ask if at this critical juncture in history

did those who were attempting to institutionalize invention get it right? Where they attempting to somehow harness and implement the forces of creative destruction or where they trying to protect against it?

Characteristics of the first generation R&D model

Companies implementing a central research lab would typically hire a noted scientist from academia to lead their R&D organization. He (almost always a male) would oversee the construction of the lab and then manage all aspects of the ensuing organization. This R&D "chieftan" alone would select the projects based on his knowledge of the technology environment and would provide status on a periodic basis to top management [25]. Innovation was primarily left solely to the scientists who toiled in the lab using a process of trial and error often modeled after the Edison approach. Genius is one percent inspiration and ninety-nine percent perspiration. The only difference was that these scientists were paid for hours not output. Actually this may be a huge difference since it potentially decoupled the entrepreneurial spirit from the persona of the inventor.

The first generation R&D era was not without some notable success stories. For example, one of the most famous outcomes of this early corporate R&D effort was the discovery of Nylon in 1939 by Wallace Caruthers while working in Dupont's central research lab. Nylon is reported to have earned Dupont over 25 billion in profits [26].

The basic first generation construct, without much change from Edison's original construct, lasted until roughly the end of World War II. By 1946, there were approximately 2000 corporate R&D labs in the US operating using the Edison first generation model [25]. The second generation R&D effort, lasting from roughly 1946 until the 1980s, was much the same as the first generation in terms of the creative process used by the hired inventor with one large exception. Government spending/investment (available to companies), along with stronger profit motivation by large firms, resulted in many more directed measures being applied to the R&D function by corporate management. In addition, after many years of relatively free reign, organizations were becoming more and more impatient for quicker return on R&D investment. Much more commercial oversight and target making were in vogue during this period. Hired scientists and R&D management who were paid to innovate were becoming much more involved in the bureaucracy of ROI measurement [25].

In 1950, W Rupert Maclaurin [7] made several keen observations concerning the country's ability to achieve breakthrough innovation. He did so after looking at one of history's great breakthroughs, specifically, the emergence of the radio industry. He also taking into account the need for creative destruction proposed by Schumpeter and also examined the behavior of corporate R&D functions in the first half of the 20th century.

His first conclusion was that the corporate R&D infrastructure would often aim at short-term incremental improvement, not "Creatively Destructive" programs. He explained: "In the United States today (1950, after ½ century of corporate R&D) our genius has lain more in applied research and engineering development, it is of critical significance to the process of innovation (proposed by Schumpeter) that we encourage a flourishing spirit of basic scientific research (leading to creative destruction).

There is a real danger that research funds will be channeled into applications where prompt results can be expected, not into unexplored areas unless an environment is established to foster this". He also looked at how the structure of industry might inhibit the natural tendency for innovation. As firms grasped some sort of (monopolistic) advantage, innovators can be affected both indirectly and directly: "The attitude of monopolists toward new developments remains ambivalent. Many behave as Schumpeter [8] suggested the first thing a modern concern does, when it can afford it, is to establish an R&D department and begin devising improvements, but according to Maclaurin [7], unfortunately, in practice, many established firms create R&D groups which are mainly window dressing with no genuine interest in radically new products". In fact, he showed examples of where presidents of large firms suppressed innovative programs because of financial impact in the short term. This observation is very similar to the one made by Clayton Christenson much later. Maclaurin [7] also predicted that as firms got larger, even external inventors (not employed directly by the firm) will have a much more difficult time finding capital from backers willing to take on the large established institutions. Finally, Maclauren did indicate that based on his view, there was a need for inventors of the 1950s to possess more technical know-how than the Marconis and other more famous early innovators since the future of invention would require a multigenerational view of emerging technologies during the inventive stages.

From 81% in 1901, the percentage of patents awarded to independent inventors/innovators dropped to about 20% by the 1980 and although there continues to be debate about the meaning of such figures such as the time period industry differences in the desire to patent, for example, and great variations in their comparative quality, the trend seems clear: modern innovation has largely become an organizational endeavor [24].

Let us examine what is being said about the hired inventor in the mid-1900s. Harvard's Charles Orth, in the early 1960s, describes the accepted ideology of the hired inventor (scientist) in the post WW II era as an individual who has a high degree of intelligence, logical, opinionated, impatient, intense, thorough, meticulous, reserved, and clannish. "More often than not, their independent way of thinking and expressing their thoughts, along with their impatience with abstractions and intuition tend to separate them from other people and to inhibit the outgoing characteristics of their personality. They normally regard conformity as a cardinal sin, and in their efforts to avoid it, they often behave in unexpected ways or become interested in the bizarre and unusual" [27]. Orth's description may in fact be accurate but the troubling element of Orth's and many other scholars' depiction of the hired inventor at the time is that this description might also describe a non-inventor who is simply mal-adjusted. In fact, Orth states that if the idiosyncratic profile is not followed in the hiring process the employee will not stay. For example if a manager hires an extrovert for the R&D assignment the new hire will soon find a different job more well suited to an outgoing disposition. Orth go on to define the proper care and feeding of the hired inventor and makes an interesting note: "Few men of science who have not made their reputation by the age of 40 will ever be regarded as at the top of their field. After 50 they begin to slow down and they lose their edge. He knows too many things and will no longer work to be creative". Like many other observers during the first 100 years of the advent of the hired inventor (1880 to 1980) doing work in the corporate R&D framework, Orth suggests that special care by management is required to get the most out of these individuals. By special care he lists; clear recognition of status, provide top notch facilities, hire colleagues of high professional status, provide interesting and important assignments and ensure a special relationship for the scientist with top management [27].

It is not difficult to see that from the description above, that unless

the rewards provided to management and other stakeholders in a firm were relatively large (in terms of successful innovation), the era of the difficult to relate to, difficult to manage, prima-donna scientist would be hard to maintain. That being said, conventional wisdom at the time kept reinforcing that the corporate R&D effort, as established, would drive great innovation. Which arguably it did (this topic must be reserved for a later report). The conventional wisdom during the first and second-generation R&D eras in the academic world tended to be quite supportive of the institutionalized R&D activity. In laymen's terms the academic thought by the great minds of the day was logical. How could crackpot individual inventors be better at innovation than massive, well-resourced R&D organizations?

James B Conant, in 1951, (while president of Harvard) stated: "As theory developed in physics and chemistry and then penetrated into practice, as the degree of empiricism was reduced in one area after another, the lone inventor of the 18th and 19th century has all but disappeared in his place in the mid-20th century came the industrial research laboratory and departments of developmental engineering." J K Galbraith also predicted the end to the individual inventor in American Capitalism: "Modern industry of a few large firms is an almost perfect instrument for inducing technological change, most of the cheap and simple inventions have to put it bluntly been made". John Desmond Bernal was an Irish-born scientist known for pioneering X-ray crystallography, and also a prominent intellect stated in 1953: Many intelligent, nonscientific people still think of invention….as the individual efforts of men of genius, instead of, as it now is, a highly organized new profession closely linked with industry and government" [28].

These quotes represent the widespread view of the inventor/innovator in the context of the firm held by most of the great thinkers during the 1940s through the 1980s. Simply stated, the new corporate machine was going to do a fine job of delivering breakthrough technology and the heroic individual inventor would not be able to compete with the teams of "hired" inventors conducting their business in the R&D lab. The representative quotations above are not only highly positive regarding the institutionalization effort but also tends to draw a linkage between the term inventor/innovator and the terms scientist/engineer. (Actually, in most cases the role of individual almost is erased from the discussion. The inventor is replaced by the engineering department or chemistry section). It is almost inferred that in order to be an inventor/innovator in the corporate R&D environment one must be a scientist or engineer or in that corporate function. This is interesting in that the terms scientist and engineer are professional designations which can be obtain through a defined vocational training program whereas innovator/inventor tend to be less tangible constructs which might relate to personality or behavior. This brings to mind a potentially silly thought question: What if during the formative years of the corporate R&D evolution, the staffing norm was to hire artists versus scientists in these labs?

In the early 1980s the second generation R&D era was winding down. New thinking was emerging that combined the desire to further reduce the uncertainty in the innovation process and also recognize that innovation in large firms required a team approach in that the commercialization process touched on many internal disciplines. In the 1980s, Robert Cooper is widely credited with building the case for a proceduralized approach to product development/innovation often referred to as a "stage gate" process [5]. The stage gate process segments the new product development process into, typically, five stages; scoping & feasibility, business case, development, testing and launch. In each stage, a cross functional team prepares deliverables which are reviewed by a management team (gatekeepers) at each gate. Stage gate is especially good for the organization of workflow in efforts to incrementally improve the performance of products or services. Traditionally, the first stage of stage gate is widely understood to be after the initial idea or creative/inventive step occurs and therefore stage gate is about implementation more so than ideation. (Interestingly, more recently Leifer et al. [1] and others have effectively challenged the use of stage gate for disruptive innovation programs since disruption or radical innovation programs unlike stage gate are often not linear in process). Starting in the early 80s until approximately the year 2000, stagegate became the be-all –end- all for modern corporate research and development organizations. Almost every Fortune 500 company adapted some form of stage gate for all forms of new product development activities [29]. On one hand, stage gate offered firms a more structure approach to the innovation process which might improve the chances for a greater number of successful programs at reduced cost, but on the other hand the move to stage gate further routinized the inventive/innovation process potentially leaving less room for creativity and as discussed above, less room for radical innovation. Is Max Weber's "Iron Cage" of rule based rational control being applied to innovation and therefore pushing the invention process toward the "polar night of icy darkness"?

Just to recap quickly, the inventor/innovator was once a heroic individual who was persistent, imaginative and with help could be entrepreneurial, then in the early days of corporate R&D he or she evolved to the hired inventors who was an ill-fitting (in the corporate context), difficult to deal with, intelligent scientist. Now, with the advent of stage gate, the role must evolve into a team player, conformist assigned to specific deliverables in the context of an integrated approach. The role of scientist in the stage gate environment is often described as quite vocational being that the actions required can be learned with time. He or she provides technical expertise, within the scope of the development target identified and his or her expertise. Deliverables are often placed in template format and are often confined within the development plan. The members of the cross-functional team (including the R&D participant) must communicate well, work well as a team and must be well versed in problem solving techniques and in experimental design. Gatekeepers manage risk in increments so the practitioners working on the team have limited need to be risk takers.

Scholar, David Mowery, argued two key points in 1984, that commercially successful innovation requires the combination of skills and information from a wide range of functions within the firm (teamwork is required), and often exploits firm-specific knowledge emerging from complex production processes (outside inventors are at a disadvantage versus those inside). To obtain information about such processes at arms-length is exceedingly difficult, fraught as it is with uncertainties and moral hazard, and frequently does not permit the effective exploitation of firm specific knowledge. Furthermore, the efficient organization of industrial research has historically been associated with the growth of a strong central staffing charge of functions such as marketing and production engineering [30].

The many valid points identified by Mowery [30], which tend to be systematic or environmental in nature were observed and discussed at several points earlier by the academic community. But while it is true that the institutional environment changed, did the accepted management theory really take into account the profile of those needing to do the inventive work? Did the inventive personality survive

the transition from the pre-R&D lab phase to the highly institutional phase, which exists during the stage gate era?

Although it is easy to see that the terrain has changed significantly in the past century, especially in the complexity of introducing a new technology to the market, it might be too much of a leap to assume that the independent inventor or innovative personality is no longer an underlying driver. The large corporation surely will be better suited with both resources and market reach to leverage a creative new invention but it seems like the personality type or role of inventor and/or innovator still must be filled within the organization somewhere and not all individuals can fill this role. Even if one assumes that scientists and engineers must hold these roles, it is probably critical to point out that not all scientists and engineers fit this persona. Could it be that the innovator/great inventor is still critically important to innovation but not able to be leveraged by the large firm? It may have to do with the innovator's inability to navigate in the corporate environment and the corporations' unwillingness to let him or her. This is not on purpose in either case but is more of a state of being. As the year 2000 approached there seemed to be a revisiting of the element of individual creativity and its impact on innovation. Could we recapture the zest of the heroic inventor in the year 2000 in the context of the large firm in order to achieve radical innovation objectives? Would the individual inventor be able to fit into the modern R&D organization?

Peter Whalley [24], observed that creative independent inventors do still survive today, and even with great technical fluency are often lost when it comes to the legalities and procedures of dealing with companies. Even if they understand the basic practicalities of their invention, many inventors lack knowledge of the everyday conventions of the business world. "Letterhead," "business cards," still less "business plans," are not everyday terms for many inventors. Whalley [24] notes that the Chicago Inventors' Council occasionally received responses to its "request for inventions" written in crayon. In a small survey of British independent inventors carried out by the "New Scientist" in 1978, of twenty eight replies: eight were handwritten. The quality of the handwriting ranged from the clear and legible to almost wholly illegible. In some cases, as if paper were a precious commodity, the handwritten answers ran to several miniature pages jam-packed with spidery scrawl. Even where letters were typed they were frequently excessively long and rambled considerably. Others indulged in a welter of irrelevancies, ranging from divorce procedures, details of family illness, burglary and surgery".

The "New Scientist" commented that this hardened their "suspicions that some inventors are their own worst enemies," but it simply indicates that these inventors are largely unsocialized in the conventions of the social world of innovation now dominated by corporations and professionals. The fact that they seem "crazy" to the insiders should not lead us to think of this as a psychological trait of inventors. Rather it is a function of their exclusion from what has become the "normal" world of innovation. It is a basic characteristic of such exclusion that those left out may lack even the basic "commonsense" knowledge of the institutional (corporate) insiders.

Based on Whalley's study, it is probably safe to assume that even if one wanted to reassemble the golden era of individual inventor within the confines of the present day research lab he or she would have a pretty immense effort to take. Corporate socialization issues are relevant not only to the individual inventor but also to the hired inventor. It is interesting to note that neither construct integrates will into the corporate organization. In fact these issues are most key in examining the construct as it evolves today.

From its beginnings, for almost 100 years, conventional wisdom was quite clear:

a. Corporate R&D was the accepted vehicle for innovation efforts (as described in the example quotes listed previously.

b. Hired inventors being intelligent, analytical, reserved and knowledgeable, although difficult to manage were the right profile for corporate invention.

In 1957, Jacob Smookler [31], after a deep investigation into patent data began to challenge the conventional wisdom including the words of JK Galbraith. Smookler suggested: "Most of us believe the independent inventor is dead and buried [31]. Most of us believe, too, that invention today has become the exclusive stamping ground of the salaried Ph.D. working in the laboratories of large corporations, surrounded by mysterious instrument panels, electronic brains, and other Ph.D's. The prevailing view was well expressed by Professor Galbraith when he wrote, "There is no more pleasant fiction than that technical change is the product of the matchless ingenuity of the small man forced by competition to employ his wits to better his neighbor. Unhappily, it is a fiction. Technical development has long since become the reserve of the scientist and engineer". There are substantial reasons for doubting the ultimate disappearance of the independent inventor. Two of these reasons pertain to independent invention on the part of technologists (in their leisure time) and two to invention by laymen. As to the former: Many hired inventors may be expected to continue to invent on their own as at present. The small volume of invention, often of considerable importance, contributed by members of college and university faculties may be expected to continue. In addition, it can be argued that inventions produced by employees of independent consulting firms should be considered as independently produced, since they are not the product of employees of operating firms [31]. "Smookler additionally challenged the correlation between advanced education (Ph.D. or professional degree – engineering) with inventive success. "We may infer from the survey that slightly over half the inventions patented currently are made by non-college graduates. Indeed, one-fifth of the respondents, a group almost certainly under-represented in the returns, did not even complete high school! The foregoing, of course, is not an argument against the usefulness of college training to potential inventors, although some have maintained such training often dulls creativity by emphasizing authority, memory, and routine solutions".

Yale scholar, Chris Argyris, in 1965, presented data examining the satisfaction drivers for hired researchers in the corporate R&D environment [32]. He also performed a critical review of the R&D institution. Argyris personally interviewed many subjects who included all levels of the R&D organization, from research director to lab technicians [32]. There are a wide range of findings from his study. In general, he concluded that researchers at the time most enjoyed the creative aspects of their work. Researchers most often cited that the most satisfying activity at work was completing a challenging technical project successfully. Argyris found that while the joy of invention was quite prominent and satisfying, according to his results there was an extremely strong negative environment in the R&D labs he studied. Attitudes of management and of the researchers were generally quite negative regarding the various interpersonal business oriented relationships that existed. According to Argyris this was primarily due to the overly bureaucratic management strategies (systematic processes, striving for efficiency, risk reduction) which put excessive pressure on the researcher and also due to the general state of widespread interpersonal incompetence of the research personnel. This

along with management dissatisfaction which leads to the bureaucratic pressure led him to theorize that the R&D organizations of the 60s were in a state of increasing deterioration. Although Argyris states that some level of management control and pressure is necessary given the profile of the researcher (lacking interpersonal skills, etc.), he is sure that given the environment and actors involved, that increases in system structure, management intervention and protocol will in fact speed the decline not reverse it. Argyris implies that the persona of the hired inventor is the source of the basic issue, he states: "At the core of the problem is the basic tendency for researchers to be uncomfortable with feelings, openness, and risk taking in the interpersonal relationships. This leads to a culture that rewards conformity, mistrust, antagonism and fear of risk taking fears eventually act to make technical problem solving (creative activity) less effective".

Argyris's investigation and preliminary conclusions in 1965 were ahead of his time. His contrarian view point is the first sign that the corporate R&D machine and the people charged with invention in large bureaucratic firms may be ill suited to truly drive significant innovation. Argyris's work not only implies that the (management) environment and strategies are at issue but also the accepted construct of hired inventor may possess some inherent flaws which if not addressed will limit breakthroughs. While this work at the time did not cause corporate America to deviate from the structured approach to development (or the future acceptance of Stagegate) or from the loyalty to the professional researcher hiring profile, it did start to sow the seeds of thought concerning the need for change in the creative approach required.

Harvard's Theresa Amabile has written prolifically since the early 1980s about the elements of human creativity and how to achieve corporate innovation through a more educated approach toward the factors in companies which motivate or potentially de-motivate the creative processes of individuals. The following is an abstract that describes concisely the view held by Amabile [2].

"Intrinsic motivation is the motivation to work on something because it is interesting, involving, exciting, satisfying, or personally challenging. There is abundant evidence that people will be most creative when they are primarily intrinsically motivated, rather than extrinsically motivated by expected evaluation, surveillance, competition with peers, dictates from superiors, or the promise of rewards. The Componential Theory of Creativity assumes that all humans with normal capacities are able to produce at least moderately creative work in some domain, some of the time - and that the social environment can influence both the level and the frequency of creative behavior". She quotes Arthur Schawlow, winner of the Nobel Prize in physics in 1981, who was once asked what, in his opinion, made the difference between highly creative and less creative scientists. He replied, "The labor of love aspect is important. The most successful scientists often are not the most talented. But they are the ones who are impelled by curiosity. They've got to know what the answer is". The component theory involves cultivating each individual's intrinsic motivation but also recognizes that creative output is enhanced by task motivation, creativity skills, and expertise. Amabile sums it up as follows: "Creative people are rarely superstars like Michael Jordan. Indeed, people whose names will never be recorded in history books do most of the creative work in the business world today. They are people with expertise, good creative-thinking skills, and high levels of intrinsic motivation. The unspoken factor is love. And (industry) should just support these characteristics instead of destroying them."

It is clear that Amabile's theory recognizes that inventors and innovators in modern corporate R&D organizations must be nurtured such that they possess the same "intrinsic" love of inventing that was identified a century ago by Veblen, Taussig and even the heroic individual inventors themselves.

Amabile is not alone, today, there is a re-focus on the importance of the inventive or creative skills required in the innovation effort of large firms. DeFillippi et al. [33] suggests that the current shift towards knowledge-based societies has turned creativity into a source of strategic advantage in the contemporary managerial and political lexicon [33]. Perhaps in the most pronounced fashion, sometimes controversial, Richard Florida, University of Toronto, even boldly claims that creativity '. . . is now the decisive source of competitive advantage'. DeFillippi reports that significant academic inquiry is now centered on the underlying interacting relationships, which were once viewed as the stroke of inventive genius by an individual but are known seen as a more complex systems theory of creativity [33]. Here is a quote by Abraham Maslow which might in some small way capture where academic inquiry might head in the future: The key question isn't "What fosters creativity?" But it is why in God's name isn't everyone creative? Where was the human potential lost? How was it crippled? I think therefore a good question might be not why do people create? But why do people not create or innovate? We have got to abandon that sense of amazement in the face of creativity, as if it were a miracle if anybody created anything.

Conclusions

Although this investigation should be considered very preliminary and in need of much more work, there are certain observations that are noteworthy; Studies of the heroic inventors/innovators (such as Edison, Marconi, etc.) indicate that "love of inventing" and a highly focused persistence, almost obsession, to move an idea to practice are common characteristics many inventors shared. The inventor's motives and persona were more similar to that of an artist rather than our modern day image of a scientist.

In addition to the latter, it is less clear, but there are indications that while the inventor/innovator obsessively innovates he or she needs a "business" partner who can relate effectively to the inventive personality and at the same time keep the commercial perspectives in sight. Most anecdotal accounts reinforce the belief that the great inventors did not invent for the financial reward.

Moreover, Early R&D directors fundamentally adjusted the understanding of the inventive personality when industry moved from relying on individual, independent inventors to employing scientists for hire to staff the R&D labs. Whereas the individual inventors were one personality type (contrivers, less formally educated, imaginative, artistic, empirical – right brained) the research directors filled hired positions with intelligent, well-trained, reserved, analytical scientists (left brain types).

The R&D institution became more and more systematic and bureaucratic as time passed. The routinization served to orient processes and staff toward less creative breakthrough activity and more toward incremental improvements. Only more recently has the recognition been given to earlier predictions that structure and bureaucracy can quench the motivating drivers of creativity, innovation, and entrepreneurship.

Academic discussion of the innovative personality and how this persona affects industrial invention has been interesting over the time period studied. Early in the discussion of the innovative personality,

economists Veblen, Taussig and others seemed to have captured the fundamental idea that a stronger than normal internal motivational element was common to those who invent. (Whether it is instinctual or behavioral, inventors were internally driven to contrive). This line of thought was derailed to a certain degree when it got caught up in the nature versus nurture debate and at the same time as many academics seemed to have downgraded the importance of the individual's impact on innovation in favor of relying on the corporation (and formalized R&D structure) to do the innovating. It was not until academics such as Smookler [31], Argyris [32] and Amabile [2] (and others) more recently returned to a focus on individual creativity and the importance of creating an environment for such creativity that the firm could create. It is interesting that Veblen's 1898 idea of the "instinct of workmanship" and Amabile's more recent discussion of "intrinsic motivation" seems to closely parallel each other.

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