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Assuring Both Quality and Creativity in Basic Research*

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ASSURING BOTH QUALITY AND CREATIVITY IN BASIC RESEARCH

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Abstract

How does one assure that both quality and creativity are obtained in basic research environments? QA theoreticians have attempted to develop *workable* definitions of quality, but in more reflective moments, these definitions often fail to capture the deeper essence of the idea of "quality." This paper asserts that creativity (as a product of the human mind) is a concrete interface between perfunctory definitions of quality (conformance to specifications) and more philosophical speculations about the nature of quality-related "ultimates" like elegance or beauty. In addition, we describe the distinction between creative ideas and creative acts and highlight one of the major inhibitors of creativity, fear. Finally we show that highly creative people often have an irreverent attitude toward boundaries and established authority, and discuss how one can allow for this when designing a QA program in a basic research environment.

Framing the Question

While QA theoreticians have attempted to nail down workable definitions of quality, most of them simply stipulate that quality "is" things like fitness for use[2] or conformance to specifications.[3] But in more reflective moments, these perfunctory definitions do not seem to capture the deeper essence of the idea of "quality." Like it or not, definitions of quality tend to get polarized on either the perfunctory or philosophical side of a spectrum. On the perfunctory side, QA professionals tend to avoid reflective speculation on the nature of "quality" because they feel that it leads to philosophical questions for which there are no "practical" answers. On the more

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[1] Fermi National Accelerator Laboratory (Fermilab) is operated by Universities Research Association Inc., for the United States Department of Energy (DOE).

[2] J.M. Juran (ed.), *Quality Control Handbook*, 3rd ed. (New York: McGraw-Hill Book Company, 1979).

[3] Philip B. Crosby, *Quality is Free; The Art of Making Quality Certain*, (New York: McGraw-Hill Book Company, 1979).

philosophical side of the quality spectrum, reflection upon the nature of quality *can* in fact lead to endless introspective musing about ultimate principles.[4]

But is there a concrete interface between perfunctory definitions of quality and unconstrained speculations about "so-called" ultimate principles like quality, value, beauty, integrity, and elegance? More importantly for our topic, are there insights which emerge from this type of analysis that can be of value to the QA professional? In what follows, we will attempt to show that clearly defining the nature of creativity is a major step toward developing a deeply compelling definition of quality that is practical and at the same time begins to capture the deeper philosophical essence of what "quality" is about, especially in basic research environments.

Creativity; A Product of the Human Mind

Defining the nature of creativity is no easy matter because creativity is a product of the human mind. So in order to define creativity, we must in some sense define the nature of the human mind *itself*; a tall order in one or two pages! I will begin by confining the explanation of the human mind to the evidence found through introspective *subjective* experience.[5] We will also assume that the mind has both a conscious and unconscious component.[6] Taking this approach allows us to characterize mental life as having three major components: 1) mental contents, 2) mental algorithms, heuristics, and combinatorial functions, and 3) a complex of beliefs about the world.

Mental contents constitute our database of knowledge about the world. Mental contents may be anything from sense perceptions (sight, sounds, touch etc.) to things we have read in books or have been told by parents, friends, movies, etc.. Mental contents come from a wide variety of experiential inputs and they accumulate over the course of a lifetime to form a major portion of our intellectual database. Other mental contents may be "hardwired" genetically into the brain and manifest themselves in thoughts or behaviors which are prior to, and independent of, the socialization or educational processes mentioned above.[7]

The second component of mental life can be characterized by things like mental algorithms, heuristics, and combinatorial functions. These are the

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[4] Pirsig's book is an excellent example of this, see Robert M. Pirsig, *Zen and the Art of Motorcycle Maintenance*, (New York: Bantam Books, 1974).

[5] This approach to the study of the mind differs sharply from more *objective* cognitive computational views of the mind and research strategies like reductive materialism and interactive property dualism. These research strategies attempt to *objectively* define the nature and relationship of the mind to the brain. For examples of the objective cognitive computational approach see Paul M. Churchland, *Matter and Consciousness*, (Cambridge, MA: A Bradford Book, MIT Press, 1986), Jerry A. Fodor, *The Modularity of Mind*, (Cambridge, MA: A Bradford Book, MIT Press, 1986), and Karl R. Popper and John C. Eccles, *The Self and Its Brain*, (Boston: Routledge & Kegan Paul, 1977).

[6] In a very simplified model, consciousness is defined as everything that one is aware of currently, while the unconscious is simply mental activity that is not in one's conscious awareness at the present time, i.e., what you had for dinner last night, your father's name, or your social security number.

[7] The arguments normally associated with the "nature/nurture" question, i.e. how much of our knowledge is hardwired into the brain and how much of it is learned by experience, are not really relevant to our discussion. Our argument about the *existence* of mental contents stands independent of the origin of those mental contents.

mechanisms by which the human mind sorts, constructs, analyzes, heuristically probes and acts upon mental contents (and presently acting experiential input) in order to forge relationships between divergent or similar things and solve problems. For simplicity, I will sometimes refer to these algorithms, heuristics, and combinatorial functions simply as *mental processes*. Like mental contents, mental processes are learned by trial and error problem solving, strategies observed in others, and over the course of our education (reading books, television, laboratory exercises etc.) As with mental contents, some mental processes may be "hardwired" genetically into the brain and manifest themselves as abilities which seem prior to, and independent of what we learned socially or throughout the course of our education. Examples of hardwired algorithms, heuristics, and combinatorial functions might be strategies used to provide survival advantage to our species.

The combination of 1) mental contents and 2) mental processes give rise to the third component of mental life, beliefs about the world. There are a number of ways that we can develop beliefs about the world. First, we can accept uncritically the beliefs espoused by others and simply down-load a fully formed belief into memory without questioning its basis in fact. Second, we can consciously reason our way to our beliefs, asking critical questions about each parameter and mental content involved and folding this evaluation (by the use of algorithms, heuristics, and combinatorial functions upon other beliefs) into what eventually becomes a new belief about the world.

But thus far we have only described the *conscious* dimension of mental life. What about all those things that you *know* but are not in your conscious awareness *right now*? While the conscious components of the above are crucial to mental life, it is their *unconscious* dimension that comes the closest to characterizing the true nature of the creative process. In other words, mental contents may be either conscious (what we are immediately aware of) or unconscious (the name of that song "that's on the tip of your tongue" but you can't remember it). Also, mental processes can be either conscious or unconscious. If we solve a number of problems and are asked to recall the exact algorithms or heuristics that we used to arrive at the solution we may or may not be able to do this. Like the name of that song "that's on the tip of our tongue", the information may be "in" there but not accessible to consciousness, at least at that time.

Sometimes beliefs seem to emerge into consciousness *intact* and appear to be the result of unconscious processes. The emergence of these unconsciously produced beliefs often occurs after one has spent an extended period of time thinking about a particular problem and come to an immovable mental road-block about a solution. By forcing our minds to think about other things (or just getting a good night sleep), the answer to the problem often emerges into consciousness almost as if unconscious processes have continued to work on the problem long after we have stopped consciously thinking about it. It's as if the *unconscious* processes have taken in all the data points and settled down on the right value or solution to the problem. We might even find ourselves in the uncomfortable position of having a belief emerge into consciousness that we have previously eliminated or are consciously opposed to as a salient possibility. This forces us to re-think our consciously held position.

It is this unconscious aspect of mental life that comes closest to characterizing the experience of the creative process. As Rollo May says, "Creativity goes on in varying degrees of intensity on levels not directly under the control of conscious willing. But let it be said immediately that unconscious insights or answers to problems that come in reverie do not come hit or miss... But what is entirely clear is

that they pertain to those areas in which the person consciously has worked laboriously and with dedication."[8]

The first prerequisite for generating creative ideas in a particular area of study is to have the appropriate mental contents and processes in *that* particular area, say high-energy physics. Without a knowledge of the contents, problem solving strategies, and parameters of high-energy physics, an individual will most likely only develop uninformed notions and beliefs about the micro-physical world. Understanding this aspect of the mind's function takes most of the "mystery" out of creativity. It should come as no surprise that people are normally creative in areas in which they have been highly trained, and worked diligently and consciously for extended periods of time.

There is, however, another aspect of developing creative ideas that is somewhat less tangible. Having a certain complement of mental contents and processes, while imperative to creativity, is not enough to *assure* it. In addition to these things, the highly creative person has to have a *connectedness* to the world which allows him/her to identify deeper underlying symmetries and relationships between (what to other people would seem like) unrelated phenomena. It is the combination of specific mental contents and processes along with this connectedness to the world that best characterizes the necessary constituents needed to produce creative ideas.

Creative Ideas and the Creative Act

But having creative ideas and being sensitized and connected to underlying relationships and symmetries is not enough to make a person *truly* creative. The truly creative person has to have the ability to move beyond *ideas* and cash-out their insights into something that can be publicly observable. In other words, the new relationship or symmetry that they identify must be concretized and communicated to others. If the creative insights are not extended through some medium that is independent of the mind of the knower, there is nothing new "created" and consequently no true creativity, for to be "creative" means, by definition, to give "birth" to something new.

One way to take a creative idea and give birth to something new is to create a *likeness* or *representation* of the idea which can be observed by others (a painting, a song, a mathematical relation, a scientific theory, etc.). Given the fact that the representation *is* a likeness of the idea, the creative person has *instantiated* this previously unnoticed symmetry or relationship for the world to see, i.e., he has *created* or given birth to something that did not exist before. For instance, one can generate a *representation* or "picture" of the inner constitution of the material substance of the universe by generating diagrams of the phenomenology of elementary particles and mathematical representations to describe their behavior.[9] We can also give birth to even less tangible representations like artistic or musical

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[8] Rollo May, *The Courage to Create*, W.W. Norton & Company, Inc., (New York: 1975), p 40.

[9] Feynman diagrams are an excellent example of the phenomenology of elementary particles with QED being an example of a mathematical representation which describes their behavior and properties. Philosophers of science may argue over how accurate those pictures are and whether the things that they describe actually exist independent of the models and observable phenomena, but they are representations none the less. See Richard P. Feynman, *QED The Strange Theory of Light and Matter*, (Princeton, NJ: Princeton University Press, 1985).

representations of trends and attitudes that we sense in our culture.[10] *True* creativity can only be seen in the *creative act*, creative acts which are publicly observable. The greatest difference between a person who *seems* to have creative talent and the *truly* creative person, is the ability to cash creative insights out into the arena of publicly observable representations be they equations, technological innovations, or a painting that captures the mood of an entire generation.

The Fear of Creativity

If creativity is such a valued and sought after commodity, why is it that society does not produce more truly creative individuals? There are at least two reasons which are equally self-defeating. First, people fear their *own* creative impulses. Deming claims, in Point 8 (Drive out Fear), that in order to achieve better quality and productivity, people must feel *secure*. He says that the word secure, comes from two Latin derivatives where *se* means "without," and *cure*, means "fear" or "care." *Secure* literally means "without fear." People are normally afraid to discuss a creative idea that they have had if it goes against their boss's position or the established way of doing business in the company. They are afraid to be criticized, laughed at, dismissed as incompetent, or adversely affected on their performance review. Deming says, "Fear takes a horrible toll. Fear is all around, robbing people of their pride, robbing them of a chance to contribute to the company. It is unbelievable what happens when you un-loose fear."

A creative individual who attempts to turn her creative ideas into creative acts which might go against her boss's or company's party line takes a big risk. Consequently, exercising creativity demands tremendous courage. "The word *courage* comes from the same stem as the French word *coeur*, meaning 'heart'... Courage makes possible all the psychological virtues. Without courage other values wither away into mere facsimiles of virtue. Without courage our *fidelity* becomes *conformism*."[11] Many times it is easier to simply conform than to buck the system. In order to improve quality and encourage creative solutions to problems, we must follow Deming's advice.

The second reason why society does not produce more creative people is the fear *of the creative person himself* by the established societal, funding, or corporate structure. Society harbors a timeless fear of creative people like artists and scientists, "For they are the ones who threaten the status quo, which each society is devoted to protecting.... It is out of rebellion that the creative act is born.... But that is precisely what makes them feared by any coercive society. For they are the bearers of the human being's age-old capacity to be insurgent."[12] It is no accident that the saint and rebel have often been the same person. The rebellion and insurgence of the creative person is often more than a mere intellectual battle, it is frequently accompanied by a tremendous intensity of affect and even rage; a rage against the system as it currently is. The creative person often finds it difficult to simply accept things "as they are."

What is it that the creative imagination rages against? "The most obvious explanation is that the creative artist or poet... must fight the *actual* gods of our society- the gods of conformism as well as the gods of apathy, material success, and exploitive power. These are the idols of our society that are worshiped by the

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10 Ian Hacking, *Representing and Intervening; Introductory Topics in the Philosophy of Natural Science*, (New York: Cambridge University Press, 1987), p 132 ff.

11 May, p 3-4.

12 May, p 19 and 24.

multitudes."[13] From an absolute refusal to accept an incomplete or less-than elegant solution to a set of physics problems, to the rage which is felt against the complacency of society, creative people threaten to undo things as they are.

Creativity and the Irreverence for Boundaries

The truly creative person is in some sense a rebel who has an irreverence for boundaries. Consequently, the creative act is a complicated mixture of isolating, defining, and breaking established boundaries in order to create new ones. Contrary to the fears of those committed to the status-quo, an irreverence for boundaries does not mean an attitude of anarchy toward *all* boundaries. It means that such things as the established laws of physics, technological boundaries, and boundaries set by limited resources are not viewed as "sacred cows" by the truly creative person.

Our knowledge about the world is actually a complicated system of theories and beliefs about the world which are nested within the boundaries of yet broader theories and beliefs.[14] Sometimes creativity can be manifested by breaking down existing boundaries within the nested context of yet larger boundaries. According to Thomas Kuhn, some of the most pronounced examples of creativity in science happen when scientists are tightly constrained within the boundaries of a scientific or technological paradigm. It is then that they often do the most creative puzzle solving.[15] During scientific revolutions, even the laws of physics are not sacrosanct as was evidenced by the acceptance of the heliocentric view of the solar system (which raised both scientific and religious controversy) and more recently in the development of quantum mechanics (which challenged the deterministic view of classical physics and our common sense view of the world).

If the laws of physics are not above such irreverence, then neither are the boundaries that have been established by orthodox QA professionals. Creative approaches to doing QA in basic research have (and continue) to challenge the boundaries that have been established by funding agencies and those from rigid orthodox QA backgrounds.[16] The argument that QA orthodoxy uses against creative approaches to quality is that such approaches do not *conform* to established interpretations and practices, i.e., "we've never done it that way before."[17] More importantly, the new approaches challenge the status quo of orthodox QA models by

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13 May, p 23.

14 In a thought provoking article, William Wimsatt describes a model of how our scientific theories and beliefs about the world are nested (generatively entrenched) within yet wider systems of theories and beliefs. Theories and beliefs that are very generatively entrenched are called "robust" because of their interconnectedness to the entire body of knowledge, see William Wimsatt, "Robustness, Reliability, and Overdeterminism" in M. Brewer and B. Collins eds., *Scientific Inquiry and the Social Sciences*, (San Francisco: Jossey Bass Publishers, 1981).

15 Thomas Kuhn, *The Structure of Scientific Revolutions*, 2nd ed. enlarged (Chicago: The University of Chicago Press, 1970), p 35 ff.

16 For a description of some of these approaches used at National Laboratories nation-wide see the proceedings of the *Workshop on QA in Basic Research and R&D*, held at Lawrence Livermore National Laboratory on January 12, 1990, published by Fermilab. I have also covered this topic in detail in Mark Bodnarczuk, *Towards an "Orthodox" Quality Assurance Program: Canonizing the Traditions at Fermilab*, Presented at the Fourteenth Annual ASQC National Energy Division Conference, Session T, September, 1987.

17 I have covered this topic in detail in Mark Bodnarczuk, *QA at Fermilab; The Hermeneutics of NQA-1*, presented at the 29th Annual Meeting of the Institute of Nuclear Materials Management, June 26-29, 1988.

challenging their validity and effectiveness in basic research and R&D environments.[18] As any creative person knows, rigid orthodoxy itself often contains the seeds of its own destruction. If the troubled nuclear industry is any indication of how orthodox approaches to "quality" actually work, it desperately needs to be challenged. Creativity is a potential resource of all members of any organization, that is, unless the organization does not allow its expression by tightening down on the boundaries and instilling fear into its employees. We would do well to heed Deming's advise in this regard.

Assuring Both Quality and Creativity at Fermilab

Given the fact that basic research environments like Fermilab have an extremely high density of creative individuals, and given the fact that a formal QA program has been mandated by DOE Order 57006.B (Quality Assurance), how does one go about assuring that both quality and creativity are obtained? How does one go about assuring the funding agency that the laboratory is being a good steward of the public trust and at the same time not set up an environment that is so rigid in structure that the creative person's irreverence for boundaries constantly puts him at odds with that system and eventually drives him out of the laboratory in search of an environment where he is free to express his creative ideas? If creativity is actually the "giving birth to" a creative idea that only a few are capable of envisioning, how does this fit into a QA orthodoxy whose traditions are steeped in repetitive production and nuclear environments? I don't claim to have all the answers to these questions, but I will now describe some approaches based upon the experience of setting up an institution-wide QA program at Fermilab. I will discuss three inter-related notions.

First (and maybe most importantly) one must set up a QA program which has boundaries that are narrow enough to assure programmatic success, but not so narrow that they stifle creativity by demanding too many layers of bureaucracy. In a recent survey of the upper management of Fermilab's Research Division, none of the management claimed that Fermilab's approach to QA stifled creativity, yet many of those interviewed had previously worked at laboratories where a rigid QA structure was in place. They unanimously said that the major difference between Fermilab's QA program and the others was that at Fermilab QA is a *line* function. It is fashionable among QA professionals today to describe QA as a "line" function, but in the day-to-day activities of their work they still give the impression that it is the QA organization's responsibility to assure quality not line management's. Even if creative people deeply challenge the boundaries of technology, mathematical descriptions of nature, or established management styles when applied to a basic research environment, they will not feel overly constrained if they are allowed (as line management) to be *the* entity that assures quality.

Second, while a QA program in basic research must have *sufficient* boundaries to assure quality, *overly prescriptive* boundaries can reduce the likelihood that creative ideas will manifest themselves and be cashed-out into creative acts. What is the difference between sufficient and overly prescriptive boundaries? The removal of *human thought* and *alternative solutions* from any given problem solving strategy. Does the problem solver have alternative ways to solve a problem at his disposal or are the solutions codified in step-by-step "written procedures" to produce conformity?

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[18] I have covered this issue in Mark Bodnarczuk, *New Directions for QA in Basic Research: The Fermilab/DOE-CH Experience*, presented at the DOE Quality Assurance Workshop, Department of Energy Idaho Operations Office, Idaho National Engineering Laboratory, Idaho Falls, Idaho, October 3-4, 1989.

How much of the process is left up to the individual and how much is prescribed by the "written procedures?" If procedures exist, they must have tight enough boundaries to assure quality, while making a spectrum of alternative avenues for carrying out those activities available to the individual. The creative person is constantly looking for new and more innovative ways to do tasks, with some of the alternatives being more fruitful or salient than others.

Third, a common misconception about creativity and QA in scientific work is that only "scientists" have creative insights and this manifests itself only at the beginning of the scientific process. In other words, after you get the scientific creativity out of the way, *then* you can pile-on the formalized, orthodox QA.[19] I have tried to show that creativity is actually a product of all human minds and manifests itself throughout the entire scope of human activities. Wherever thought and problem solving is demanded, *there* you will find the potential resource of creative solutions. In high-energy physics, the creativity does not magically stop once the ink of the calculations for particle production or state-of-the-art detector R&D is dry. Creativity can be exercised prior to the design, during the design, during the installation and operation of the experiment, and during the data analysis and publication stage.[20]

In the final analysis, the problem of dealing with creativity and the fear it inspires in so many people is a question of one's ability to tolerate the presence or absence of *boundaries*. Creative people love to immerse themselves in intellectual chaos in order to bring it into a new ordered relationship with other knowledge about the world. Other people (like rigidly orthodox QA professionals) seem to need a familiar structure in their approach to problem solving from the very beginning. It is not that one cognitive style is "better" than the other, it's just that they are suited for solving different kinds of problems. If the problem is straight forward and orthodox in nature, then using a familiar method to solve it will probably suffice. If however, the problem involves finding new innovative solutions to problems which have been robust in the face of known methods, one must be irreverent toward as many of the parameters as necessary to find a solution. In a basic research environment like Fermilab where the goal of the Laboratory is to heuristically probe and define the fundamental constituents of the universe and the forces by which they interact, the creative approach is essential. The challenge of an effective QA program in this type of environment is to assure that the structure of the organization is sufficient to assure programmatic success, while at the same time not taking itself (and its authority) so seriously that it will not allow even its "most sacred" tenants to be challenged by a creative person's irreverence for established boundaries.

The deepest essence of the spirit of creativity and the creating of new boundaries at the cost of old ones was captured by one of western civilization's

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19 One writer who takes this view is Richard J. Garibaldi, "Creativity and Quality Assurance," published in the *Proceedings of the Fourteenth Annual ASQC National Energy Division Conference*, September 13-16, 1987.

20 I have argued elsewhere that the entire process is confined by various levels of peer review which are set up by the scientific and engineering communities, see Mark Bodnarczuk, *Peer Review, Basic Research, and Engineering; Defining a Role for QA Professionals in Basic Research Environments*, Presented at the Sixteenth Annual ASQC National Energy Division Conference, September 17-20, 1989.

greatest minds, Albert Einstein, when he said, "For rebelling against every form of authority, Fate has punished me by making me an authority."[21]

Conclusions

While we may continue to use more perfunctory definitions of quality in our work, reflection on the role of creativity in QA breathes new life into what can easily become dead and lifeless QA orthodoxy. By viewing creativity as something all humans have, the QA manager and line management can capitalize on this much sought-after resource and encourage their employees to cash-out their creative ideas into reality. Also, we QA professionals should not check our creativity in at the door when thinking about how to design a QA program for *any* environment. We can prevent this by following Deming's advise and "Drive Out Fear." We should encourage personnel to have a critical/irreverent attitude toward boundaries, accepting them only when they have been closely scrutinized. Boundaries that do not survive the gauntlet of peer review, should be candidates for the circular file.

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[21] Heinz Pagels, *The Cosmic Code; Quantum Physics as the Language of Nature*, (New York: Simon and Schuster, 1982), p 18.