How We Know What We Know About What We Know, And How We Learn It.

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Introduction

Our goal tonight is to leave you excited about seeing your work from a fully new and fresh perspective. I'm not going to cover this material with the rigor needed to suggest you would abandon any of your old beliefs. We are only asking you to hold those old beliefs a little less tightly and to be open to learning more about some new ways of thinking.

This century will prove every bit as revolutionary in Western thought as the 16th century was. We hope to introduce you to several elements in this rushing torrent of exploration into what it is to be human. Each of us needs to choose to what degree we will embrace these new findings. This is undoubtedly the most exciting time to be living in over 400 years.

In this evening's talk, we would like to leave you questioning your beliefs about the nature of reality, experience, and learning in ways you may never have questioned before.

We would like to unfamiliarize you with wisdom that has been conventional for our lifetimes.

I'll start by providing a broad-brush view of Western thought concerning the nature of reality. We'll move from the Medieval Age into the Enlightenment and the early Modern Age, and then from the late Modern Age of the 20th century into the Postmodern Age. I want to show that new learning has turned conventional wisdom on its head at times in the past. It is unsettling to find ourselves in that same condition, but it is not unprecedented. We must make individual and collective choices about where we are going to be in this revolution: defenders of the conventional wisdom or explorers of the new world.

We have a lot of ground to cover… Let's get going…

The Sweep of History

Medieval Perspectives

The norms of medieval thinking seem very strange to us. We're looking back through 400 years of post-Enlightenment progress. In some ways, it could be said that "common sense" prevailed. Folk wisdom prevailed. What was the shape of the earth? We didn't experience curvature *directly*, so the earth is flat. What is the nature of a body (like a ball) set in motion? Our direct experience "proved" that such a body's nature was to come to rest (more about this later). From where did the insect life of a pond come? Direct observation says that the elements in the pond must have spontaneously combined to produce the insects.

The model of the human health from the Medieval Age is especially interesting. The model that prevailed in Europe for most of a century was the theory of humours, and their balance: sanguine, phlegmatic, melancholic, and choleric. Bleeding and purging were the principle treatments to restore balance. Why did this make so much sense for so long? Think about it: if the whole body has a fever, why would you hypothesize that the problem was in a specific point?

The folk wisdom for celestial mechanics also came from direct human observation. Lived experience told us that we are on a motionless platform with all the things visible to us being bodies in motion in the celestial sphere. Copernicus turned all that upside down in the late 15^{th} century with the hypothesis that the sun is a stationary sphere with planets in orbit. It's interesting to reflect that the established institutions of the time rejected his view, but at that time he was mostly ignored. His views were radical but not viewed as a threat.

One hundred years later, Galileo wrote in support of Copernicus's view when he discussed his observations of the several planets and the moons of Jupiter. By that time, however, the established institutions were sufficiently threatened by a rising tide of radical new ideas that he was imprisoned. The old ways of viewing the world had come under great enough attack to warrant a genuine counter attack.

From where we stand in history, it is difficult to understand where all this resistance to new perspectives came from. It's important for us to identify how foolish these ideas seemed at the time when compared to the common sense of lived experiences. In the midst of this understandable skepticism and resistance, all of Western thinking was revolutionized in the next hundred years.

Enlightenment Perspectives

The potency of these new ways of looking at reality created an unstoppable force of discovery. The 17^{th} and 18^{th} centuries were an amazing time. Newton, Descartes, Bacon, Leibniz, Kant, and others created what became the major disciplines of study today. The basic perspectives established then have been carried well into the 20^{th} century.

Let's look at several of these changes. In medicine, analysis of the human body led to the knowledge that the heart is a pump, that the stomach and intestines are a chemical processing system for delivering nutrients to the rest of the body, that the nervous system connected the brain to all of the rest of the body. As importantly, disease mechanisms were discovered showing illness having point sources. All of Modern medicine represents incremental extensions on these initial Enlightenment era discoveries.

Newton especially revolutionized mechanics with his radical approach. The calculus of motion he developed to capture his hypothesis has taken us to the moon and back. Stop and think about it: no one had ever seen a ball thrown that stayed in motion. Things that moved always slowed down and stopped; that's the nature of things. Then along comes Isaac Newton who says just the opposite. He says that the inherent nature of bodies in motion is to stay in motion unless acted on by other forces. That is, things slow down and stop because there are always forces around that have that effect. It was an amazing breakthrough that defied every experience that we as people have all of our lives; yet it works.

What is the engine that has driven this explosion of discovery? One key element has been the mind-body dualism espoused by Descartes. This dualism set up a number of assumptions about the discovery, or scientific, process. The core assumption is that we can measure, think about, and apply logic to our observations about ourselves and the world around us. That is, we can make observer-independent conclusions.

Other foundation stones of our Modern thought are the belief in linear causality and the subject-object split. Our assumptions about these are now so deeply embedded that we rarely even think of them. Of course every effect has a cause. This belief underlies all didactic teaching, all standard project management, all engineering, and all "root cause" failure analysis.

The key assumptions in this view are:

1. Analysis of the parts elicits truth about the whole. Breaking things down into their parts is the way to learn about complicated systems. Conversely, complicated things can be built from simpler parts.

2. Elemental systems are linear. This means that small inputs will produce small outputs and large inputs will produce large outputs. This assumption calibrates how we relate to the world at very basic levels. If this linearity isn't present, we assume we've proved that the system is not elemental, but is a complicated combination of elemental systems instead.

3. We believe that the world is deterministic, that is, that all effects have explicit causes.

These assumptions are the core of what has become known as the scientific method and, we should never under-appreciate their potency. Our ability to explain and control the physical world around us is indeed awesome. As a materials scientist, my own contribution to our knowledge of the physical world was gained using these tools.

Our Era: Late Modern Perspectives

The 19th century saw the application of linear reductionist thinking to all aspects of our world: the physical, the social, the psychological, and the religious. A belief grew throughout the Western world that we were on our way to a complete and total understanding of the entire world.

The Royal Society in England was established in 1662 to promote this new method of inquiry. It became the premier society of its type in England and one of the several most prestigious societies in Europe. Only the most accomplished scientists were elected to membership. In the 1890's, the Royal Society commissioned a poll of its esteemed members to collect their thoughts on two questions:

- What fraction of all there is to know about the world has already been discovered?
- When will we know *all* that there is to know?

Of course, even asking these questions was an expression of linear reductionistic thinking. The results showed that most members believed that 70-90% of all knowledge had already been generated and that in the following decade the rest of all knowledge would have been discovered.

Not only did they misapprehend their ignorance, the decade 1900-1910 turned out to be a revolutionary time in physics. Two important things happened in that next decade. First, Ernest Rutherford published his model of the atom that included, for the first time, a dense nucleus at the center with electrons orbiting at great distance (comparatively). This was a radical change from the then-accepted model that matter was smoothly distributed in solid materials. At the same time Albert Einstein published his Special Theory of Relativity. He showed that Newton's laws of motion didn't always apply. Between them, everything that we now know of as nuclear physics was born.

Thus began a century in which the more we learned, the more we knew that we didn't know. All of the certainty of the 19th century dissolved in an explosion of new questions.

Let's look at the state of cognitive science at the close of the last century. In this area of study, the impact of Cartesian dualism was profound. The desire to analyze the brain as a rational, calculating device had been expressed by Descartes (1596-1650) and Leibniz (1646-1716). By the mid-20th century, technology and philosophy had entwined to produce the metaphor for the brain that carries through to the present: the brain as a computer. Rafael Nunez and Walter Freeman term the resulting line of study "cognitivism." In writing of the last 50 years, they say: "As a consequence, the entire domain of the science of cognition became narrowly defined as 'the study of intelligence and intelligent systems, with particular reference to intelligent behavior as computation.' This reductionist characterization became synonymous with 'Cognitive Science'. Cognitivism had not only *defined* Cognitive Science, but also it had *prescribed* how to conceive and carry out any true science of cognition."

This metaphor for the human brain as reasoning machine is at the core of the theory of representationalism. In this view, our brains use symbols to create a representation of the real world. Thus, education is the process of creating and refining that representation. We are "right" when our representation correctly maps to objective reality, and we are "wrong" when it does not. Our brains are linear, rational machines that take data, store data, conduct operations on those data, and generate responses. This is the metaphor in action.

If you want to use your computer to do a task, you first upload the necessary software programs to actually perform the tasks. The programming steps in the code explicitly do small, linear tasks that, together, accomplish complicated activities. You then input the data particular to your need. Finally, you tell the program to operate on the data in order to generate a result or response. And when you finish, you make sure that you save all of your work to disk.

From a representational perspective, teaching is, then, the process of "uploading" the "software" to handle the data and "uploading" the data to be manipulated by the "software". This would be what happens, metaphorically, when I learn something new. Any practice I do after the learning helps move the software and data out of short-term memory into long-term memory (the learning) so that the software and data aren't lost.

This view carries a common sense aspect that has helped representationalism eclipse any other view. Listen to your language and to what others say and write. You will hear the computing machine metaphor repeated continuously.

Postmodern Perspectives

Work in physics, biology, the medical sciences, and the social sciences in the last 50 years has lent weight to much of what in speculative philosophy is known as Postmodernism. There is no focused, simple definition of what the term "Postmodern" means. I refer here to the hypothesis that there is not an objective, detached (dualistic) explanation for events (a unifying metanarrative). This is not a discussion of Postmodernism, but I think that an image from Jean-Francois Lyotard (as summarized by Paul Cilliers) nicely describes the two basic reactions to Postmodernism.

> Different groups (institutions, disciplines, communities) tell different stories about what they know and what they do. Their knowledge does not take the form of a logical structured and complete whole, but rather takes the form of narratives that are instrumental in allowing them to achieve their goals and to make sense of what they are doing. Since these narratives are all local, they cannot be linked together to form a grand narrative which unifies all knowledge. The Postmodern condition is characterized by the co-existence of a multiplicity of heterogeneous discourses – a state of affairs assessed differently by different parties. Those who have a nostalgia for a unifying metanarrative – a dream central to the history of Western metaphysics – experience the Postmodern condition as fragmented, full of anarchy and therefore ultimately meaningless. It leaves them with a feeling of vertigo. On the other hand, those who embrace Postmodernism find it challenging, exciting and full of uncharted spaces. It fills them with a sense of adventure. Which of these two evaluations apply is often determined by whether one feels comfortable without fixed points of reference. The choice between the two is determined by psychological just as much as theoretical considerations.

The results of several decades of work in the neuro-sciences, linguistics, and biology have produced this vertigo in those fields and philosophy. The work has profound implications on our understanding of how we, as humans, create a reality from our sensory experiences, *i.e.* learning. We'll now survey the new directions this work establishes and begin our exploration into the implications for teaching and mediating.

The Sum of Current Study

Our awareness about how the brain is structured and what its chemical and electrical activity looks like has forced us to rethink our comfortable assumptions and metaphors. I'll give a quick glimpse into these newer learnings. These are the results of experimental findings, not the speculation of philosophers. In that sense, our theories, models, and philosophies must coherently incorporate these findings. The purpose of this introduction is not to make a rigorous case for any of them, but to point the direction for your further investigation.

The Mind is Inherently Embodied

The brain is a neural network, a network of neurons that connect to one another to create the most complex structure in the world. The physical structure *and* its electrical activity are dynamic and distributed. We know that this network behaves in a complex fashion as the network responds to and adjusts to stimuli. For instance, with color recognition, there are not specific neurons that respond to "red" and others to "green". The network as a whole responds differently to different colors.

We know that specific parts of the brain are specialized, but the neural activity within the specialized regions is distributed in this fashion. In fact, the research shows that the brain is plastic enough that it can adjust and change specialization if needed. Our neurons unmake and remake connections throughout our lives. That dynamic plasticity in the morphology of the brain may slow down as we age, but it doesn't stop.

This means that human thinking is not software running on a standard hardware platform. Our entire nervous system is the embodiment of all our experience. There is no disembodied logic that I can exercise separate from the embedded neural activity of my brain. Something called *universal reason* isn't discernable or testable by the embodied human mind. Our brains are *not* representational. Instead, lived sensorimotor experiences generate and stimulate neural structures that interact and respond in complex ways with the whole structure. In turn, neural connections that are used and reused are strengthened. The connections that aren't used dissolve and disappear. The reality we experience is the complex whole generated by this plastic structure and its activity.

One consequence of this picture is: the doing *is* the learning. The whole sensorimotor experience (motion, touch, seeing, hearing, smelling) co-forms the neural response. The neural response then co-forms the sensorimotor experience. If the "learning" activity is different from the “doing” activity, two substantially different neural activities are involved and the crossover benefit is limited.

Thought is Mostly Unconscious

Think for a moment about all the “thinking” that goes into producing what you see. There is signal processing on your retina, at the junction with the optic nerve, at the vision center of the brain, and then throughout the rest of the brain. To none of this do we have conscious access. In fact we know that the optical information arriving in the brain constitutes only a coarse image. We’ve also learned that the part of the brain specialized to recognize shapes is different that the part specialized to recognize faces. Yet, we consciously experience a seamless, high-resolution image. All of that processing is part of the cognitive unconscious.

Speech is also an incredibly complex activity that generates a great amount of unconscious brain activity. When cognitive scientists list the activities necessary (in a representational way) to form even a simple sentence, they end up with dozens of steps. These all occur nearly instantly in the neural networks of our brain without our having any conscious access.

Lakoff and Johnson have called this cognitive unconscious the “hidden hand that shapes conscious thought.” Have you ever found that the harder you thought about something the more the answer eluded you? And that when you “quit thinking about it,” the answer just came to you? That’s an example of how our conscious thinking can actually get in the way of how our brains really work.

Again, the doing *is* the learning. Consciously constructing logical representations can be useful, but by far most of our thinking activity goes on outside our awareness or control. The unconscious activity influences the dynamic plasticity of the neural network just as potently as our conscious thinking. All of this unconscious activity co-forms our reality in uniquely human and individual ways.

Abstract Concepts are Largely Metaphorical

This is an intriguing topic all by itself. Linguist George Lakoff has been exploring metaphorical constructs for three decades. In our late Modern age educations, we were taught that metaphors were the wonderful tools of poets, playwrights, and novelists. Serious scientists, we were taught, avoided metaphors and described abstract concepts directly. Lakoff and Johnson thoroughly demonstrate that the descriptions of abstract concepts that scientists are most proud of turn out to be deeply embedded and camouflaged metaphors.

As a quick example, we'll take the abstract notion of "time." Our sensorimotor experiences are of numbers (counting) and motion, and we've made our timepieces accordingly. But they "tell" time; they aren't time itself. In our culture, time is perceived through two primary metaphors.

The first metaphor is that time is a dimension. Here time is either stationary and we move along it, or we are stationary and time is moving by us. Consistent with a dimension, the present is a point in time with the past in one direction and the future in the other direction. Events are in the near past or the distant past. Our motion on that dimension works like any other motion: time can go fast or slow. Isaac Newton built a calculus for his laws of motion that treats time as a dimension in exactly the same way that those laws handle the three dimensions of physical space. This is clearly a potent and useful metaphor, but it is a metaphor.

The second metaphor is time is a resource or commodity. This shows up in expressions such as, "I don't have enough time." Or, "I waste too much time." A fascinating feature of our minds is that we use many metaphors simultaneously, just as with time, to hold our whole experience and perception. You and I don't experience any dissonance or stress from the fact that these two metaphors for time are incompatible. We hold them at once and move seamlessly between them depending on the circumstance.

The awareness of this facet of human experience has profound implications in how we create a reality and how we learn. Metaphorical mappings are a natural feature of neural networks. Metaphors reside in harmony with the network structure of our brains.

Metaphors are very powerful tools in constructing reality. We can limit possibilities by being unaware of the metaphors we're using, or we can create new possibilities by choosing new metaphors. Individual experience also has a powerful effect on this aspect of perception. Just listen to the metaphors an engineer uses to describe a sunset compared to the metaphors an artist uses for the same scene. In this way each new experience is in intimate co-formation with the complex whole of the person's life. What each person "learns" from an experience is only to a small extent defined by the experience; the formative context plays the dominant role.

Human Systems are Inherently Complex

Throughout this talk I have been differentiating between things that are complicated and things that are complex. We have already discussed the importance of the linear reductionist approach to all of the knowledge developed over the past 400 years. Along side these advances we have come upon problems that have proven very resistant to analysis, description, and prediction. The last 30 years has seen intensive study of this class of systems. Several alternate approaches have been pursued. Together they have loosely come to be known as complexity science.

Chaos theory has evolved to understand one set of systems: those that are hypersensitive to the starting conditions. Such systems are not substantively different from other determinative systems, but their behavior is extremely difficult to predict accurately because of this initial condition dependence. Weather is one such system. Such systems may be unpredictable, but the basic characteristics of the system can be reliably modeled. Walter Freeman and others have conducted some modeling of brain function, but there appears to be limited applicability of chaos theory to human thinking and human systems.

In contrast complex adaptive systems theory is proving a much richer topic of study. These are systems that have several properties in common: they are made up of individual agents that are connected in a network. These agents have some degree of freedom to choose their own response to stimuli from their neighbors. As a result, the systems comprised of these agents are self-organizing and capable of creating novel outcomes. There is much current debate about exactly how to characterize these systems, but this general description will have to suffice. This definition would qualify the neural network of our brain to be a complex adaptive system. It would also say that a community of people interacting is a complex adaptive system. The implications of this seamless continuity between individual and collective human cognition are only beginning to be explored.

These complex systems represent a wholly different set of systems from those that are complicated yet reducible. Complex systems cannot be understood with traditional analysis tools. First of all, these systems function as an integrated whole that cannot be broken into subsystems. All the agents participate in subtle ways in the system response (the system response is distributed). When complex systems are studied, linear causality can be deduced retrospectively, but cannot be predicted prospectively. These systems are not determinant; cause and effect are not uniquely coupled. And, most important, complex adaptive systems can produce truly novel, unexpected responses. Whether in the study of the neural network of the brain or in studying the behavior of communities in conflict, we are only at the embryonic beginnings of our understanding of how these systems create new possibilities and outcomes.

Reflections About the Meaning of These Findings

How can I be so certain that we are entering a new era of change as great as the Age of Enlightenment? Haven't schools of philosophical thought come and gone without lasting impact? Maybe we'll be lucky and Postmodernism will turn out to be a fad that will pass. I'm sure faculty at most universities in the 17th century Europe felt that way about Francis Bacon and others who argued for the supremacy of empiricism and the scientific method over all other sources of knowledge and wisdom.

During the Age of Enlightenment, it was the experimental evidence confirming the speculation of some philosophers that anchored a true revolution in thought. The research results profoundly changed the debate. It was no longer simply different schools of philosophical thought debating the nature of reality; it became a matter of which hypotheses were confirmed by observation and measurement.

As powerful as linear reductionist analysis has proven to be, it could not unlock the mystery of complex adaptive systems. We can send men to the moon and return them using these tools. We can lift massive metal machines like 747's into the air and fly them for thousands of miles with these tools. We can create an internet with them.

But we now know that we can't understand how individuals or communities think, learn, and create reality with these tools alone.

In the 16th and 17th centuries, there were observations made by early physicists, chemists, and astronomers that insisted many old ideas be abandoned. Today the research results of biologists, neuro-scientists, linguists, and others cannot be ignored either.

All this leads to a new universe of questions for our field, including:

- How is the experience of conflict expressed in the network response of the human brain?
- How would conflict be characterized among disputants using concepts of complex adaptive systems?
- How do we understand the experience of conflict given that the reality of the conflict is being dynamically co-formed by the disputants both internally and interactively?
- How can we "train" mediators given that representational assumptions about learning have been shown to be wrong?
- If the mediator is a co-formed and co-forming part of the complex network in operation during mediation, what does neutrality mean?
- What does "resolution" mean?
- Can there be a claim to "objective truth" in mediation?

I'll now return to a comment I made at the opening of the discussion: We would like to unfamiliarize you with wisdom that has been conventional for our lifetimes. The next two days will be spent listening to workers in other disciplines telling us about teaching and learning from their professional perspectives.

While this talk has been a discussion of the progression in Western thought, I'll end with one small piece of Eastern thought:

True wisdom is in the question, not the answer.

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