How Measurement Works

William Bricken
December 2007

One fundamental difference between Science and Art is that Science relies upon numbers in general and measurement in particular. There are several different kinds of numbers, just like there are several different types of Art. The concreteness of numbers, their connection to physical reality, makes Science different than Art.

The meaningful use of numbers relies upon making a measurement. *Measurement* is an act of comparison, an object to be measured is compared to marks on a standardized measurement tool. *What a number means* differs significantly when what is being measured is physical (e.g., measuring distance using a ruler) or non-physical (e.g., measuring knowledge using a multiple choice test).

The simplest use of numbers for measurement is *tally arithmetic*, the idea of making a single mark that corresponds to a particular object. This is the way that physical items have been tallied, or counted, for ten millennia. The collection of marks illustrates the number of objects, even after the physical collection has been disbanded.

•••• + ••••••• = •••••••••••

A closely related idea is to climb a counting ladder, one step at a time. We give names to each step (*two*, *three*, *four*…) and thus construct shorthand labels that permit convenient reference to a multitude of tally marks.

4 + 7 = 11

Numbers are used to describe physical attributes. We first define a *standard unit*, such as a meter, or a pound, or a second. Then we construct a *measuring tool* by calibrating a physical object using the standard unit. Measuring tools construct automatic tallies using standard units (i.e. they count). *Every meaningful number* is read from a tool that is calibrated by some type of standardized unit. Analogously, in the Art of written language, every idea is read from words that are defined by some type of intended meaning. The difference is that words do not require a physical referent (they can refer to concepts) while numbers do require a physical referent (they cannot refer to concepts). Thoughts, for example, are notoriously difficult to count. The idea of "one-and-a-half concepts" does not make sense.

Counting specific objects is *precise*. However, a degree of imprecision is introduced into the idea of measurement when we try to read between the unit marks of a measurement tool. This imprecision converts integer numbers (tallies) into *statistical numbers* (probabilities). Statistics puts meaning into the numbers that result from inexact measurement by positing that there is, in fact, a True measure, but that the numbers we read from the measurement instrument are fuzzy. Given a True measure of 50, a fuzzy numerical measurement may at one time read "48", but at another time read "56". Actually, all measurement tools yield fuzzy numbers, either at a fine grain of detail, or due to physical disturbance and/or human error during measurement.

We can never know a True measure by looking at a statistical number, all we can say is that an observed measurement is close to the hypothetical True measure, within some degree of accuracy. The wider the range of ambiguity around an observed measurement, the higher our level of confidence is that the True measure lies within that range.

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             True        observed
               ↓            ↓
-----------{-----------------------------------}-----------
           /                                    \
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range of confidence around an observed measurement

All statistical numbers within the range of confidence have the same meaning since they refer to the same True measure. For purposes of measurement, the observed number 54 (illustrated below), with an accuracy of ± 8 units, has the same meaning as the numbers 46 and 62, and all the other numbers in between. The main idea of statistical numbers is that *within the range of confidence, different numbers mean the same thing*.

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            True=50    observed=54
               ↓           ↓
-----------{-----------------------------------}-----------
           /                                    \
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46 < *range of meaning of "54"* > 62

Analogously, the meaning we read into a written word is only somewhat close to its intended meaning. Fuzzy words permit, for example, "cat" and "feline" to convey the same idea. Taking a statistical number to *be* the True measure is analogous to saying that every word has one and only one exact meaning.

Statistical numbers have been applied to the measurement of non-physical things, such as a student's knowledge. Measurement of non-physical properties is always *approximate* for three distinct reasons:

1) *Ambiguity*: We can never know what the True measure is, or for that matter, whether or not a True measure exists, because there is no concrete Real thing to define what True means.

2) *Reliability*: All non-physical measurements are fuzzy because calibrating a measurement instrument is very difficult when there is no physical referent.

3) *Validity*: The standard unit itself is inexact, can vary between measurements, and is usually poorly defined both technically (*measurement validity*) and conceptually (*content validity*).

Hopefully, our decisions are guided by True measures; hopefully we seek to avoid mistaking a finger pointing at the moon for the Moon itself. Scores on the widely used COMPASS placement test, for example, have a published range of accuracy of about ± 8 points on either side of an observed score. A student with an observed score of 54 most likely has a True score between 46 and 62. But to say that the particular score of 54 differs from a score of 46 or a score of 62 is to call upon an Artistic rather than a Scientific use of numbers.

HOW SOCIETIES FAIL
William Bricken
April 2008

This material is from Jared Diamond's book, Collapse.

Diamond identifies a dominant factor of societal collapse: "ecocide", or environmental suicide. Dozens of former societies have brought about their own destruction in eight different ways:

deforestation -- destruction of the habitat, primarily by cutting down all the trees
soil destruction -- erosion, salinization via fertilizers, and fertility loss by overuse
water management -- pollution, redirection, and overuse of available fresh water
over-hunting -- killing and eating other species, usually large mammals
overfishing -- depleting fish stocks and undermining fish reproduction
introducing new species -- importing species that compete with native species
human overpopulation -- too many people for the natural resources to support
per capita impact -- individuals taking too much for their personal benefit

Four new self-destructive ways have recently been introduced:

human-caused climate change -- a type of over-pollution which Nature balances
buildup of toxic chemicals -- manufactured chemical concentrations
energy shortages -- overuse and over-reliance on sources of energy
human use of plants -- monocultures and over-farming

What is different about today's societies is that we are triggering all 12 of these self-destructive catastrophes, and all will become critical within the next few decades. Diamond believes that we will avoid apocalyptic collapse, instead we face "...a future of significantly lower living standards, chronically higher risks,and the undermining of what we now consider some of our key values."

In the past, individual societies have collapsed (in Rome, Greece, Crete, Iran, China, India, Cambodia, the US Southwest, Peru, the Yucatan Peninsula, New Guinea, Pitcairn and Easter Islands, Bolivia, Cambodia, Iceland, and others). Today there is one global society facing one global collapse.

What determines whether or not societies succeed the the face of catastrophe includes:

-- how much damage a people inflicts on their environment
-- the degree and impact of climate change
-- hostile neighbors
-- decreased support from friendly neighbors and trade partners
-- a society's response to its problems (degree and timeliness)

The primary villain in today's ecocidal tendencies? Big business.

THE MATHEMATICAL ORIGINS OF INTEREST-BASED BARGAINING

William Bricken
May 2008

Modern negotiation technique and strategy found its beginning in game theory, a branch of applied mathematics which studies strategic situations. Game theory was formalized by John vonNeumann during the 1940's and developed extensively during the following decades, primarily at the RAND Corporation in Santa Monica. John Nash (who's life was fictionalized in the film A Beautiful Mind) contributed to the precursors of game theory by studying equilibrium situations in the social sciences. In such situations, people tend not to change.

Much of our common wisdom about interpersonal behavior in bargaining, negotiation, and potential conflict situations comes from game theory. The zero-sum game, for example, characterizes adversarial interaction, where the winnings of one party become the losings of another party. All fair sporting contests are zero-sum games. Former Secretary of State Henry Kissinger was an avid student of game theory. Lose-lose diplomacy, practiced by the US government as MAD (Mutually Assured Destruction) for several decades, comes from the study of a game called the Prisoner's Dilemma. (Vice-President Cheney's shock and awe tactics also derive directly from game theory.)

Interest-based bargaining (IBB), which is constructed on the win-win principle, comes from the Prisoner's Dilemma game also. Since the structure of this game (and many other games that characterize a diversity of interpersonal interactions) is a well-understood mathematical object, an understanding of how games work can contribute to the success of IBB. I'll describe the simplest case of the Prisoner's Dilemma for context.

The Prisoner's Dilemma

Mathematical games specify a payoff matrix for two or more players. The payoff matrix is simply a list of what each party wins or loses on each round of play. A round of play consists of parties simultaneously casting votes, or providing information that determines the result of that round. Each party votes at the same time, however they can communicate with, solicit, threaten, bribe, encourage, and/or befriend each other freely between rounds.

The Prisoner's Dilemma involves limited communication between parties. Here's the story: The police apprehend two suspects in a crime, who happen to be working together and are also guilty. Before being questioned separately they can devise a strategy. Both can go free if they each provides an alibi for the other. Both can be jailed if they admit guilt. This establishes the win-win and the lose-lose conditions. The win-lose condition, which creates the negotiation tension, is that each can plea-bargain for a lighter sentence by saying that the other is guilty. What would you do? Would you rat on your accomplice to save your skin, or would you trust that he would not rat on you?

To put the same game in a different context, consider two gas station owners on opposite sides of an intersection. If they both keep prices high, both win. If one cuts prices, he gets more customers (win-lose), that is until the other owner cuts prices even more. This results in a price war, in which both make less and less profit, the lose-lose situation.

Consider two parties at the bargaining table. The stronger one party gets, the weaker the other gets, in terms of likelihood to win by establishing their position. This is classic adversarial bargaining, where neither party particularly cares about the cost to the other, so long as they get what they seek. But if the negotiation is not zero-sum, then there also exist solutions in which both parties win, and in which both parties lose. Much of the IBB process is finding those win-win solutions.

The Payoff Matrix

A game payoff matrix helps to clarify negotiation strategies. In the simple game, the payoff matrix consists of four cells, rows defining what Party 1 wins or loses by voting YES or NO, columns defining what Party 2 wins or loses. In the table below, if both parties win or lose together, the consequence is little, but either party can win big by voting NO when the other party votes YES.

	Party 2: YES	**Party 2: NO**
Party 1: YES	+1 (Party 2) +1 (Party 1)	+3 (Party 2) −1 (Party 1)
Party 1: NO	−1 (Party 2) +3 (Party 1)	+0 (Party 2) +0 (Party 1)

The payoff matrix provide a rich mathematical structure; in particular the relative magnitudes of potential winnings (and losings) define effective negotiation strategies. Effective means that we can determine the best way to vote in order to maximize gain. The heart of IBB is to maximize the mutual gain of both parties. In the above matrix, note that this can be accomplished by a trusting relationship in which each party takes turns losing a little while the other wins big (alternating YES-NO and NO-YES). But the strategy changes if there is only one vote, only a YES-YES vote will permit both parties to win.

What This Means for LWTC

Even without delving into the books on game theory and political negotiation, we can summarize some important points about how IBB must be structured. For example, IBB is a YES-YES voting strategy, so the idea of taking turns with wins and losses is not available. This means that the optimal joint gain may be less than the optimal possible gain for both parties.

Perhaps the most important observation is that explicit entries in the payoff matrix are mandatory. You cannot develop a coherent strategy without knowing the gains and loses. More directly, all Interests in IBB must be explicitly defined and quantified, and these definitions and measures must be consensual. This is also common-sense bargaining: it is a good idea to know the value of what you are buying.

We also known (mathematically!) that lessening communication between parties drives a game from win-win to lose-lose. All transactions must be transparent and open.

The relative balance of costs and gains within the payoff matrix is critical. Kissinger and Nixon made NO-NO so onerous that anything else was a better alternative. (They also strengthened this by convincing the other parties that they were completely crazy, and thus could not be relied upon to avoid the onerous payoff.) Of course, knowing the relative balance of payoffs also requires anchoring possible decisions to explicit quantitative measurements.

The LWTC negotiation has many aspects, each with its own payoff matrix. In IBB it is necessary to define all these matrices prior to voting. Thus there is a premium in IBB for arriving at consensual definitions of the territory, and for redefining territories that may drive the process into positional, YES-NO moves. The general idea is to eliminate (or to make onerous) all payoffs that are not YES-YES. That is, Positions must have very high costs. And unilateral redefinition must be prohibitively expensive. Note that trust is not mandatory if the costs themselves make destructive moves self-destructive.

Underneath most mathematical analyses is an assumption of rational behavior. Self-destructive (ie NO-NO) moves are available strategies only when they later provide YES-YES situations. An explicit payoff matrix exposes the use of NO-NO moves (examples: 60 student classes, walking out of the negotiation) as tactical. Self-destructive tactics is not permitted in IBB.

The key that makes IBB work is the ability to redefine the payoff matrix so that all rational moves are YES-YES. The territory must first be defined consensually, the payoff then measured consensually, and then the decisions made rationally. It is known that rational decision-making is much easier and more common when the game is explicit.

ADVISING IS GLOBAL TEACHING

William Bricken
June 2008

> "An excellent advisor does the same for the student's entire curriculum that an excellent teacher does for one course."
> Mark Lowenstein, 2005

This essay was inspired by a thread on Tomorrow's Professor, and an article entitled: "Academic Advising in the New Global Century: Supporting Student Engagement and Learning Outcomes Achievement" by Susan Campbell and Charlie Nutt.

The central idea is that academic advising is an educational process on the same level as teaching course, but with a global rather than a classroom perspective. As such, it is an essential part of the assessment of student outcomes.

Providing Opportunity

A recent change in how we think about teaching has been to move from a teacher-centered experience to a student-centered experience. Teacher-centered we all know about, the professor conveys information and demonstrates skills while the student receives instruction. Student-centered focuses on the behavior and the experiences of the student as the outcome of the educational process. One movement that incorporates student-centered education is the recent focus on "student learning outcomes", the idea that the success of an educational program is measured by what the graduating students can do. Teaching is all about student success. Institutions strive to construct value-added experiences that provide opportunities for students to engage in their own learning.

Academic advising shares the same goal: to provide opportunities for students to engage in their own learning. Advising does this by directing students toward activities that will enrich their experience and their capabilities. The opportunities for engagement that are addressed by advising include curriculum choices, strategies for success, extra-curricula options, student learning outcomes, and personal counseling. Academic advising addresses the totality of the student experience, from first visit to campus to graduation day. It includes guidance in meeting basic skill prerequisites, in choosing a major field of study, and in appropriate conduct while on campus. In contrast to classroom teaching, which addresses knowledge and behavior in a narrowly defined subject matter, academic advising is global. It is an integral part of the learning experience and the glue that provides coherency to the college experience.

It is through advising that students can engage in a perspective beyond their own opinions and desires. An advisor not only seeks to fit coursework to a student's own needs, she seeks to broaden a student's choices by introducing new and unexpected potential, by suggesting alternatives throughout the educational process, by seeing the student experience as a whole. And critically, advising plays a central role in student retention.

Institutional Effectiveness

The comprehensive assessment of the quality of an educational experience not only requires measurement of the outcomes of student experiences, it also requires the connection of learning outcomes to choices in curricula and in extra-curricula activities. These choices originate in the advising process. Therefore assessing educational quality through learning outcomes is intimately connected with improving the advising process.

Academic advising plays a global role in student success and in campus-wide achievement of mission and objectives. It is the formal institutional service tasked with caring for the structure and sequence of a student's educational experiences. Institutional assessment attempts to connect the behavioral consequences of a course of study to projected institutional changes that may improve those behavioral consequences. Since advising contributes substantively to the educational choices a student makes, it is also an essential component of the assessment of the quality of institutional structure, since learning outcomes arise from educational choices.

Good advising develops a clear plan of action that meets specific objectives for learning, it explores options and opportunities, it constructs a clear set of expected outcomes, it calibrates student satisfaction with elected courses of action, and it identifies appropriate measures to assess the alignment between student achievement and student retention. As well, student advising contributes integrally to program enrollment and planning, to meeting the mission of the institution, and to defining and measuring what is meant by student learning outcomes and by institutional success.