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Basic Social Math: A Linguistic Upgrade for Decision Analysis and Social Dynamics Research.

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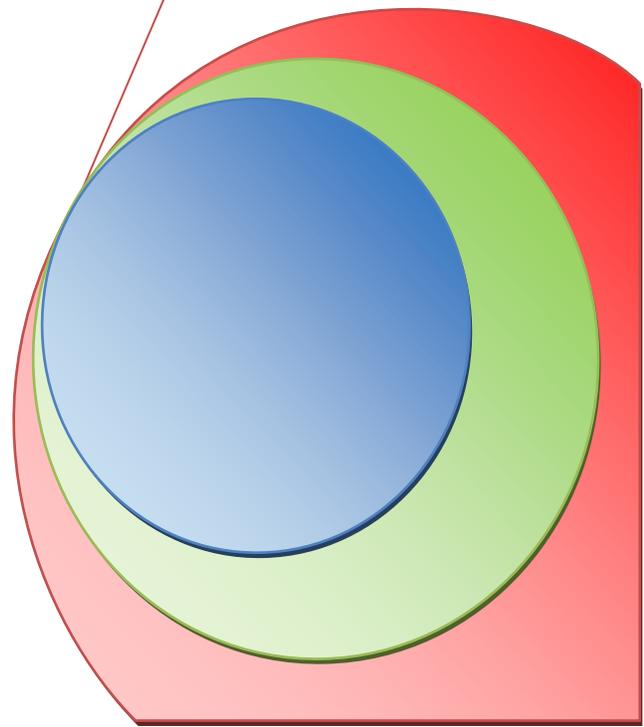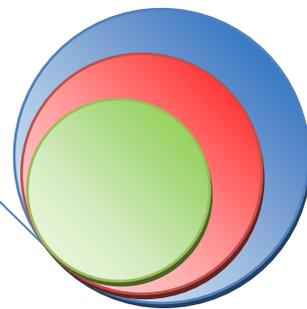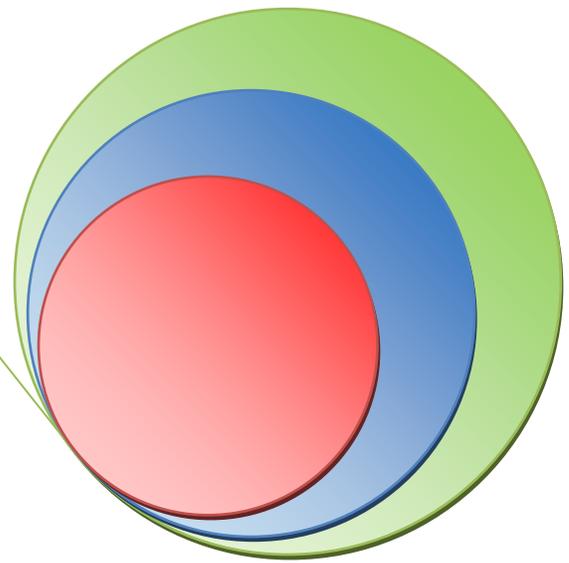
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Basic Social Math

A Linguistic Upgrade for Decision Analysis
and Social Dynamics Research.

Jared Lee Hanson

9/9/2009

Advisor: Patrick R. Moran

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This thesis by Jared Lee Hanson is accepted in its present form.

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"If I have seen further it is only by standing on the shoulders of Giants."

– Sir Isaac Newton

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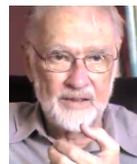
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Abstract

There are foundational errors in the mathematical frameworks currently used in Economic and Decision Theories. Recent systemic failures in the interdependent business and educational sectors also show that many practices based on these theories are unsustainable in the changing dynamics of the global economy. A new approach is needed in social science research and systems engineering. This paper examines how the new understandings of complex systems, the role of emotion in cognition, and the core dynamics of decision making can help us correct these errors and to create a general framework for systemic innovation. It argues for the development of more rigorous linguistic tools that can objectively analyze social dynamics from an empirical perspective rather than from subjective cultural frames. In order to upgrade theories and adapt practices in social and educational systems, we need to first correct problems at the fundamental end of the mathematical framework that is used for such analysis. Examples of complex systems are explored within the operational context of cross-cultural language and insurance classrooms at Yamamah University in order to define the methods and illustrate the approach of Basic Social Math to correcting errors and testing theories in the social sciences.

Educational Resources Information Center (ERIC) Descriptors

Instructional Innovation

Social Values

Neuroscience

Psychology

Mathematics

Non-linear Dynamics

Decision Analysis

Complex Systems

Table of Contents

The author's perspective reflects experiences in many cultures even though his focus is on KSA & USA.
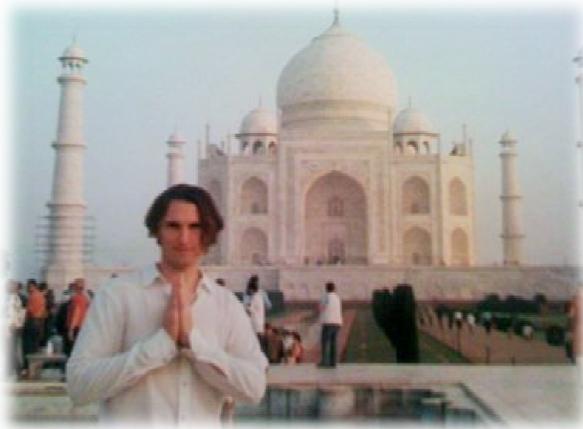
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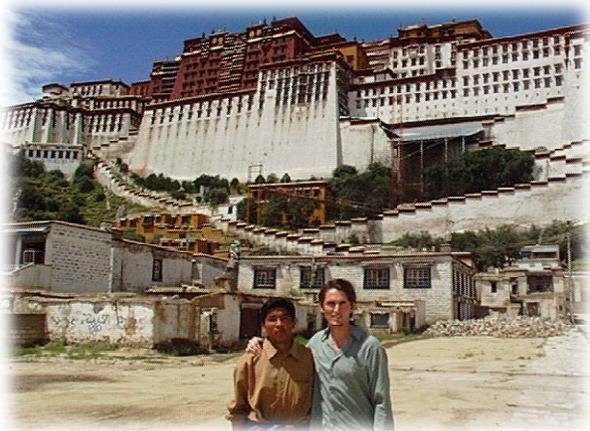
Lhasa, Tibet

Masai Mara, Kenya

Riyadh, Saudi Arabia

Introduction

If you can raed tihs, tehn you can do mroe mtah tahn you mhgit tnihk.

Did you konw yuor biarn is diong clalcuus to decdoe tihs mssaege?

Taht konwdlgee can hlep us slvoe smoe big pbrlomes!

The above exercise gives a simple illustration of how the brain performs non-number calculations in order to operate in the complex system of language. This new understanding is supported by the physiological evidence that is coming out of neuroscience and psychology from studies supporting a new theory of the mind. Physiology studies have revealed that 80% of the nerves going into the visual cortex of the brain come from areas associated with memory, while only 20% come from the eyes (Gawande 2008). If so little input comes from the outside world, how does the brain create such detailed pictures of everything we see? Only calculus is capable of such integration.

Above we see how the brain uses key bits of data input, and then draws on information already stored in its neural networks to create a complete picture of what it perceives. With language, the brain performs this calculus using the symbol system of the alphabet and the underlying rules of grammar in order to calculate meaning as demonstrated above. This is enlightening because it helps us see how the brain operates in even more complex social interactions; ones that involve the calculation of non-number values for decision making in complex systems.

Though we may not be conscious of it, math is a functional component in the complex system of language. This awareness opens doors to a new understanding about how such systems work. The math, in this case, is helping us decode the complexity of language. Knowing how math operates in complex systems provides the basis for decoding such interactions into comprehensible patterns. The reason your brain can do the calculus that decodes the message above is that, among English speakers, the 'arithmetic' of the letters and words has already been standardized and follows a common set of rules. Without these fundamental components firmly in place, as we will see later in the case of second language learners, the calculus is impossible. The brain simply gets lost in the complexity and cannot find any meaning.

In a recent op-ed column about the Grant Study that followed the class of Harvard students which included John F. Kennedy, David Brooks, of *The New York Times*, commented on the failure of the researchers to find meaning in the complexity of outcomes. "The study had produced a stream of suggestive correlations," he writes. "But it's the baffling variety of their lives that strikes one most. It is as if we all contain a multitude of characters and patterns of behavior, and these characters and patterns are bidden by cues we don't even hear. They take center stage in consciousness and decision-making in ways we can't even fathom. The man who is careful and meticulous in one stage of life is unrecognizable in another context." In the face of such disparities, Brooks concludes, "There is a complexity to human affairs before which science and analysis simply stands mute" (Brooks 2009).

Brooks' conclusion, however, only pertains to the traditional approach that was used in the Grant Study and to the broader failure of the analytical approach most commonly used in the social sciences today. When we examine the framework of math that is currently used for analysis in economics and other complex social interactions in operations research, we find that fundamental components are missing or contain errors.

This creates the same kind of problem that prevents the brain from decoding the complexity of language into meaningful patterns. This is an interdisciplinary problem that arises from both linguistics and from mathematics. Jonathan Barzilai, a professor of industrial engineering at Dalhousie University, has recently demonstrated that the mathematical foundations used in the social sciences need to be corrected. He concludes the following:

> Classical decision and measurement theory are founded on errors which have been propagated throughout the literature and have led to a large number of methodologies that are based on flawed mathematical foundations and produce meaningless numbers…. In particular, foundational errors in utility theory, game theory, mathematical economics, decision theory, measurement theory, and mathematical psychology need to be corrected. (Barzilai 2009)

The corrections that are needed require that practitioners, educators, and researchers work in a new direction that might appear counter-intuitive. The errors in question originate from the fundamental end of the mathematical spectrum. Yet the overwhelming majority of research today is conducted at the sophisticated end of math.

Social science researchers and economic theorists have, for the most part, approached math as a tool to be molded in ways that support their existing theories and applications rather than the other way around. In physics, people used standardized scales of measure and rigors of math to chisel away at their ideas and test their theories. In social science, people start with a theory and then try to tweak the numbers and mathematical formulations to support their conclusions.

But the framework of math used in social science is incomplete and incoherent, especially at the fundamental end. Hence, any theories, formulations, or conclusions we come up with using the current framework will also be incomplete and incoherent. Many errors exist because our approach to math is backwards. We often start with conclusions and try to find numbers and data that support them. Math

is an afterthought rather than a tool that we use to test assumptions and generate data that can lead us to more accurate conclusions. We just don't use math in that way for problems of decision making.

Professor Barzilai explains more, "The common view in the classical literature that group decision making cannot be modeled mathematically is an error that is based on a misinterpretation of the implications of Arrow's Impossibility Theorem. Decision analysis is not a prescriptive theory and will not be a sound theory until these errors are corrected" (Barzilai 2008).

As for Brooks' conclusion about complexity, we know of many examples where science has spoken volumes about complex systems. Perhaps weather stands out most prominently. Many social and natural phenomena are now recognized as complex systems, such as cities, economies, ecologies, political entities, and societies. The problem is not that science has nothing to say, but that our approach has robbed social science of its most important means of expression—math.

The new scientific paradigm of complexity is putting math back into our analytical approach and helping us correct the fundamental errors cited above. Agent-based modeling is one area of work that provides a useful framework for unraveling the components of complex systems, so that we don't get lost in the "baffling variety" of what we see.

Agent-based models are simulations made up of autonomous agents that interact within a set context. Based on the constraints of their environment and a few simple underlying rules, complex patterns of behavior emerge in these systems.

Pictured here is an Agent-based Model from John Conway's 'Game of Life' named Gosper's Glider Gun:


http://en.wikipedia.org/wiki/Conway's_Game_of_Life

It's an animation that shows the complexity that can emerge from the interaction of a few simple underlying components (the animation can be viewed online at the link shown here). These models are useful because they help us see the underlying structure of complex systems. They help us look for, and identify, a limited set of interacting components that are responsible for the unlimited variation and complex outcomes we observe. All of its complexity emerges from three simple rules and the constraints set by the environment.

The complexity in human affairs is no different from what we see in these Agent-based Models. Another easy way to visualize the structure and relationships of complex systems is to look at the relationship between the three primary colors and a masterpiece painting. All of the complexity we see on the painting's surface is based on underlying combinations of three colors and their simple rules of interaction. When we understand the relationship dynamics of the underlying components in the

system, we can decode all the complexity that we observe without getting lost or confused. This helps us see how so much variation is possible from so few, relatively simple components interacting.

Language is another example of the same kind of complex system. It is made up of a limited set of sounds that we combine in different ways to produce words. We combine words according to a limited set of grammar rules and produce a very large variety of expressions. From the exercise above, we see that the brain is using math throughout the process to both encode and decode the complexity. So, we find again that something doesn't quite add up in Brooks' conclusion regarding science and human affairs. We are overlooking the math. Ironically, we are choosing to ignore very basic math in our analysis of complex social problems. Math is the language of science. If we want science to speak to us about social interactions, we have to begin with the math.
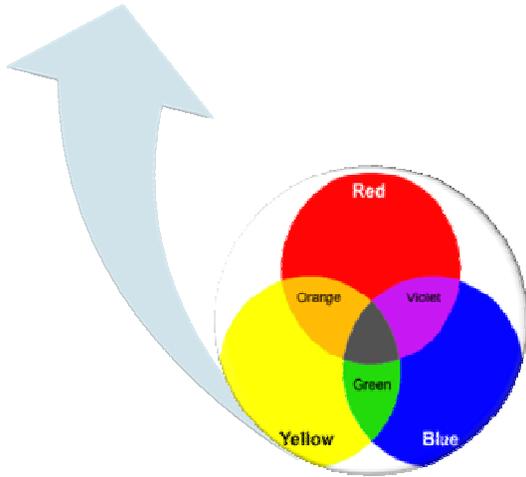
This paper presents an argument for a new conceptual framework for describing and explaining the phenomena that take place in social interactions. It is intended for readers across a wide range of disciplines.

I propose Social Math as a conceptual framework that can help identify the patterns in these interactions and explain how to manage such patterns toward a particular outcome. In this paper, I concentrate on the social interactions that occur in a language class; however, the applications of Social Math are relevant for other social situations.

Social Math emerged from my earlier work in the insurance industry, where I developed a framework to elucidate decision-making processes to ultimately help individuals avoid financial losses. When I later encountered the Experiential Learning Cycle (Kolb) in graduate school, I quickly saw the connections between these two frameworks. The process of establishing a relationship between the two, along with my examination of my English language classes at Yamamah University in Saudi Arabia, led me to a deeper exploration of patterns and a greater recognition of the need to further develop the concepts of Social Math.

The paper begins with a definition of Basic Social Math, where I propose that the patterns and relationships in social interactions can be addressed through the language of math, particularly in terms of articulating abstractions and processes, which I believe to be universal, thus transcending cultures and instructional contexts.

In the next section, Situation in the Field, I present the field of Operations Research, a quantitative approach to decision-making in order to situate the development of my own model of decision-making and the connection to the experiential learning cycle.

In Purpose, I explore the cultural dimensions of Social Math and make the case that its components are independent of any culture.

The Rationale section presents arguments from selected sources for the application of math to social phenomena as a key tool in furthering our understanding of these phenomena. Social Math is one such tool.

In Examples, I discuss how social math can be used to decode the complexity of language and culture and go on to describe in detail how I used Social Math to analyze interactions that occurred in my English classes in Saudi Arabia.

In the next section, Applications, I analyze in detail the problem of decision making in complex social interactions, namely those that arose in my English classes. I discuss at length the decision-making model, the experiential learning cycle, and how Social Math informs and enhances an understanding of what goes on in such interactions.

The Analysis section shows another application of Social Math in my English class, the intersection of competing or conflicting values held by participants in social interactions.

Finally, in Synthesis, I shift the discussion to education in general and some of the problems there. I argue that Social Math can help address such problems, particularly through re-framing these problems based on mathematical principles.

As an argument for a new conceptual framework, there are necessarily areas that I have not fully addressed or explained. My proposal maps the territory in a broad, general way, and I recognize that to fully articulate a new theory, more research is needed. Social Math, as I envision it, crosses or joins many disciplines and fields of study. To fully develop these connections requires exploration and synthesis on a scale that is beyond the scope of this paper.

The purpose for developing such a framework is to get a clearer picture of the general dynamics that underlie relevant patterns in complex operations, like a classroom or a business. The objective is to establish better ways to solve problems and engineer environments so that desired outcomes, like learning or profitability, can be optimized in systemic ways that are flexible, scalable and transferable across cultures and contexts. Correctly applying the math to such interactions constitutes a major technical breakthrough for management science and social dynamics similar to what the pioneers of flight did for the interactions of aerodynamics.

Again, my intention is to chart the direction of this new conceptual framework, Basic Social Math.

Chapter 1: Definition

In order to introduce and define what Basic Social Math is, it's necessary to first describe the context in which it can be used and the purpose it can serve.

The name itself is a starting point. The term 'Math' is broadly defined as the study of pattern. The adjectives refer to the level of complexity and the specific types of patterns that are being studied: 'Basic' and 'Social.' In essence, the idea is to place values associated with patterns of social interaction into a more rigorous linguistic frame by applying fundamental rules of math to calculations involving social values. Patterns of social interaction can assume various forms, but for the purposes of this paper, I focus on the classroom and what happens when teacher and students engage in activities that are designed to promote learning. The patterns that emerge from this engagement are many, but I concentrate on those related to decision-making and experiential learning.

Creating such a framework involves the synthesis of ideas at the intersection of four major disciplines—Math, Neuroscience, Linguistics, and Psychology.

In order to help illustrate the nature and function of this new framework, this paper closely examines management problems in complex operations using primary observations from the cross-cultural classrooms of Al Yamamah University in Riyadh, Saudi Arabia, and secondary observations from education in the United States. A classroom was chosen because it is inherently a social context where the interactions are between two or more autonomous individuals, not a single individual acting in isolation. Neither does the classroom operate in isolation, but as an interdependent extension of the larger socioeconomic systems.

It is in this context of social interaction that we will seek to identify the conditions that enable the application of mathematical operations to the empirical manifestations (actions and results) of different values (desires and decisions) in the interactions. In other words, the teacher in a language classroom prepares content and activities with intended learning outcomes and presents this to students in class. Students bring their own backgrounds, previous experiences, and levels of language proficiency. They also bring their own feelings, desires, and intended learning outcomes. When the lesson begins, teacher and students engage in the process of language learning. What then ensues are the complex interactions that bring out the interplay of manifestations (actions and results) and of values (desires and decisions). Defining and explaining this interplay, seen from the perspective of Social Math, involves naming the relevant patterns and organizing them into a framework.

The two key patterns present in the classroom are the Experiential Learning Cycle and Elements of Choice. The former is an iterative sequence of activities or stages that learners undertake in order to

learn any subject matter. The latter is a cycle which features stages of decision-making. These two patterns, I contend, are universal. That is to say, they apply to all learners, regardless of learners' cultures or the contexts in which instruction occurs.

As an example, how can we explain what happens in the classroom when the teacher invites students to take initiative in a certain activity, and the students do not respond as the teacher expected?

Instead of completing the assigned homework, students trade completed work with their friends and turn it in as their own.

The teacher is faced with a decision at this point.

How is he to respond?

If we employ Basic Social Math to help us understand this teacher's situation, we would not be seeking solutions, but rather patterns—the underlying dynamics involved in the students and their learning in connection with the teacher's intentions and decisions.

Does he call the student out for cheating and humiliate him in front of his peers?

Or, does he find a way to turn the situation around so that the student becomes aware of his mistake in a way that does not damage the operational relationship between the teacher and student?

We would look at the underlying basis of the teacher's decision priorities and the constraints that limit what types of actions are, or are not, acceptable as a means of achieving the desired result. We would look at the neurobiological systems that are in operation during the decision-making process instead of the singular decision made in the immediate social situation.

A central feature of this framework is that it is 'linguistic.' The word 'math' may be misleading for those who tend to see math in terms of numbers, equations, formulas, and other numerical applications. Math also deals with abstractions, relationships, and patterns. Although these can be represented in numbers, they are also represented through language, which is the approach I take. When I say that Basic Social Math is a 'linguistic framework,' I refer to the terminology, the language used to describe these patterns and their relationships.

The problem with using natural language for this job is that many of the fundamental rigors of math can be ignored or misapplied without detection, which creates skewed pictures of the relationship dynamics being observed. Hence, there is a need to standardize and apply math's fundamental rigors to the linguistic framework used in such analysis in order to improve accuracy and transparency as well as to uncover flawed logic. So I'll begin by illustrating problems that are visible in a linguistic context, but also applicable to decision making contexts involving complex social interaction.

Here's a less complex example from linguistics that parallels the problems in question and shows how the underlying patterns of existing frames clash with each other under the surface of the complexity:

_This is the class not bad It's good,
BBut they. Groop not bad but some
Student more the fire. And some Student
trieding lering English and exuiting._

Here the 'calculus' that delivers meaning, as illustrated in the exercise at the beginning of the introduction, doesn't work. It doesn't work because the Saudi student who wrote this did not use the place value structure of English. He is using the underlying structure of his first language, Arabic, as the basis for what he is trying to communicate in English. This shift in the underlying structure causes the communication to get lost and the meaning doesn't come across. A speaker of English, who doesn't have any knowledge of this Arabic structure, will have difficulty decoding what this student is trying to say because there are two different systems of linguistic calculation in play here. They are not immediately visible, but they represent the structural level of cognitive processing that Basic Social Math deals with in the larger context of social operations.

What we see happening in the linguistic example also happens in the operation of organizations and cultures where different value calculations are used in the underlying decision making of social interactions. The problem only becomes visible when the two systems interact. Just as the student cannot see that he has made a mistake, so too is it difficult for those operating within one cultural context to see problems they create by operating the same way in a different cultural context. This is happening more and more in the global context of interaction.

In this paper I focus on the problems than an American teacher encounters in the operation of a classroom in Saudi Arabia, but the same problems arise for any business operation that was established in one culture and now operates in another. As in the student writing example, the question becomes one of making the 'calculus' work again to deliver the goods, so to speak, when we shift from one context to another. How do we create consistency and alignment in the underlying value structures of these interacting systems so that meaning or performance comes across as efficiently as it did before the shift in operational context?

 We'll first seek to answer that question in the linguistic context with ultimate aim of shedding light on the more complicated operational problems we now face. This is not the type of problem that statistics is capable of dealing with. It's a values and naming problem that is more suited to the humble tools of arithmetic.

Therefore, Basic Social Math is not to be confused with statistics, where we are estimating numbers based on a sample, as in surveys and polls. It's also not an attempt to turn massive data sets into useful

information. Nor is it an effort to translate social problems into numbers that can be used to calculate some solution. Instead, it is about identifying general patterns of interest within a social context and understanding the real world dynamics of their interaction. Identifying these patterns involves finding the terminology for both the patterns and the interactions.

Based on this clarified view, Basic Social Math is a framework that can then be used to approach problems in new and creative ways that utilize all the tools math has to offer. The interactions in teaching require the use of such tools in doing the assessment, gauging, and calculation necessary for the teacher to determine where students are in their development of target skills. These are math-based operations that simply have not been standardized for general application. They require much more than simply knowing the right answer to a given problem. In order to perform such operations accurately and effectively, teachers need a deeper understanding of the mechanics behind both the social interaction and the neurological development that constitutes learning itself.

To illustrate this need, let us consider research into the knowledge of teachers of math as a subject in itself. In a recent article written for *The New York Times*, Pam Grossman, a professor of education at Stanford University, elaborated on the mental mechanics behind the teacher-learner relationship. Citing work on the teaching of mathematics at the University of Michigan, she said that it "has demonstrated that what they term 'mathematical knowledge for teaching' distinguishes teachers from mathematicians and more effective teachers from less effective ones." In other words, the knowledge required to do the operations of mathematics is not the same knowledge required do the operations of teaching mathematics.

Here, they are making a distinction between non-math and math-based knowledge of the social mechanics in teaching; with the math-based knowledge being linked to effectiveness. Grossman also explained that "over time, good teachers can anticipate predictable errors and misconceptions, understand the logic behind the error, and help move students toward a deeper understanding" (2009). I contend that this, in turn, requires a clear view of the decision making and social patterns that underlie the mechanics of learning, in other words, Basic Social Math.

As we take another step up in the complex operations of our education system, we see that it's not just the mechanics of learning that are of concern, but also that administrators are now struggling with the mechanics of getting students into the classrooms to begin with. Kate Zernike, also in the *NY Times*, gives us another example of how fundamental mathematical operations, not statistics, are being used to analyze the decision making of parents and prospective students.

> As colleges weigh this year's round of applications, high school seniors are not the only anxious ones.
>
> Just as nervously, colleges — facing a financial landscape they have never seen before — are trying to figure out how many students to accept, and how many students will accept them.
>
> Typically, they rely on statistical models to predict which students will take them up on their offers to attend. But this year, with the economy turning parents and students into bargain

hunters, demographics changing and unexpected jolts in the price of gas and the number of applications, they have little faith on those models.

> "Trying to hit those numbers is like trying to hit a hot tub when you're skydiving from 30,000 feet," said Jennifer Delahunty, dean of admissions and financial aid at Kenyon College in Ohio. (Zernike 2009)

This situation begs the question of why the statistical models aren't working. In the face of such rapid change, using traditional statistics is like driving your car down the freeway, but only looking in the rearview mirror. The statistical models work fine as long as the road ahead looks somewhat similar to the road behind you. But in the global economy today, the pace and scale of change is both rapid and far reaching. This requires that data be analyzed in more forward-looking ways where decision equations can be customized based on new and emerging conditions. Again, that is not something that statistics was ever designed to do. Zernike explains how administrators have had to alter their approach to solving the operational problem of getting students into their classrooms.

> Colleges consider an amalgam of factors, comparing them to past trends, to predict whether a student will attend, including, for example, what high school he went to; the strength of his grades, scores and recommendations; how much financial aid he has been offered; and whether he plays the cello or wants to study ethnobotany or economics. (If he is a she, the equation looks different still.)

> They consider how many phone calls, Web hits, campus visits and applications they have received. They look at how many students put down a deposit in May, then assume a bit of "summer melt."

> If it sounds complicated, it also works. Kenyon, for example, has hit the magic hot tub each of the last five years. (Zernike 2009)

As you can see, the focus of this effort to increase enrollments is not about compiling statistics on potential students. Instead, the focus is on the decisions that these students are engaged in making, and more specifically, on the patterns and processes present in these decisions.

Hence, along the same vein as this "mathematical knowledge for teaching" and these customized decision equations, Basic Social Math can be more generally described as the study of patterns in the dynamics of fundamental, social interactions incorporating the linguistic rigors of basic math (e.g. consistency of measure, scalability, logic, etc.) into the non-number calculations and decision equations used for the purpose of problem solving and engineering in social systems. It's essentially a linguistic upgrade for general decision analysis, discovering and employing the language to describe such decisions.

Viewed from a much broader perspective, it's a framework for the study of fundamental patterns, dynamics, and cycles related to social interaction at all levels; from the microscopic neurobiology of the brain to the macroscopic socio-cultural systems of the global economy. It's a mathematical framework

for identifying and validating universal constraints, operating rules and general laws of social interaction that can be used to deconstruct, analyze, simulate, and engineer various social systems in education, business, and government. Such a framework could contribute greatly to our understanding of social systems and to our ability to improve or enhance interactions within these systems.

To my knowledge, such a framework has neither been standardized for general application nor is such an approach widely used in the study of social interactions. In fact, the absence of this kind of analytical framework is a source of many of the problems that we are experiencing in our social systems today. This is not to say that mathematics is not used in various disciplines of social science, rather that a unified and complete framework extending from the fundamental to the sophisticated levels of math has not been developed or put into practice. I propose Basic Social Math as the basis for such a unified and complete framework.

There have been efforts to this end, but flaws have emerged. For instance, the math that has been developed and put into practice contains uncorrected errors as Professor Barzilai has demonstrated. He elaborated on what is needed:

> The construction of the mathematical foundations of any scientific discipline requires the identification of the conditions that must be satisfied in order to enable the application of the mathematical operations of linear algebra and calculus. Because these conditions have not been correctly identified in the literature, the fundamental problem of applicability of mathematical operations to scale values has not been solved and these operations are applied in error in game theory, economic theory, psychology, and other social sciences. In particular, addition and multiplication are not applicable to any scale values in decision theory. (Barzilai 2007)

Since this is such a deeply rooted and far-reaching problem, Basic Social Math essentially wipes the slate clean and begins from scratch with the empirical systems of neurobiology and linguistic frame of math.

To return to the focus of this paper, the purpose for developing such a framework is to get a clearer picture of the general dynamics that underlie relevant patterns in the complex operations, like a classroom. Informed by this clarity, the objective is to establish better ways to solve problems and engineer environments so that desired outcomes, like learning, can be optimized in systemic ways that are flexible, scalable and transferable across cultures and disciplines. As I noted in the introduction, correctly applying the math to such interactions constitutes a major technical breakthrough for social dynamics similar to what the pioneers of flight did with the interactions of aerodynamics.

Next, I will discuss where this analytical framework fits in the broader management and social sciences.

Chapter 2: Situation in the Field

For the purposes of this paper, the cross-cultural classrooms at Yamamah University constitute the empirical system that we will observe and seek to solve problems in. In this context, we want to optimize the complex outcome of learning; that is to achieve the best possible result for students in acquiring target skills/knowledge. To do so, we have to work within the changing dynamics of each class, which is a live system made up of autonomous agents. These are areas of focus for two existing fields of study and application of mathematics to social interactions—Operations Research and Agent-based Modeling.

For optimization, we will examine the framework and methods of Operations Research, a quantitative approach to decision analysis and engineering that was developed during WWII. To cope with the uncertainty and changes of complex systems, we'll draw on the framework and methods of Agent-based Modeling (or Multi Agent Simulations), a method for modeling and studying complex systems made up of multiple interacting agents. We are going to take a look at current challenges in applying these methods to solving real-world problems. We want to see how these analytical frameworks fit together as a linguistic frame so that we can begin to correct some of the errors that are connected to the larger problems of the social sciences.

In the June issue of *ORMS Today*, Wolfgang Ketter and F. Jordan Srour at the Rotterdam School of Management of the Erasmus University wrote about the tradeoffs between optimization in O.R. and agent-based methods:

> The need for well-calibrated input can be a significant challenge in complex environments. As Bastiaan van de Rakt, a joint owner of INITI8, remarked, 'O.R. methods fail in very complex and dynamic (inter) organization structures and are difficult to use for detail-level analysis since the focus is on high level parameters. It doesn't explain events on a small scale.' This same concept was eloquently stated by Joost van Dijk of DEAL Services when he said, 'O.R. tends to freeze reality.' (Ketter and Srour 2009)

While it is true that the field of Operations Research employs many sophisticated mathematical tools to analyze social interaction, we have never extended these industrial strength tools down to the general consumer level nor have we corrected several foundational errors. Indeed, we have developed optimization tools at the Calculus level, but we haven't standardized that framework for social calculations at the Arithmetic level. 'Calibration' and 'detail-level analysis' comes from expanded and rigorous linguistic processing of data at the Arithmetic end of the mathematical spectrum. Before we begin talking about "values" in any specific context of social interaction, first we need to understand how language systems generally affect the mental mechanics of calculating value.

The calculations we do in social interactions are not based on numbers, per se, but that doesn't mean we cannot seek to incorporate the same calibration that numbers provide: i.e. placeholding, preservation of scale, precision in measurement, increased capacity to record details and fluctuation, etc. Here are examples of how the symbol systems of language and mathematical principles interact to at the Arithmetic level of calculating meaning. The first is a saying from Confucius:

焚。子退朝，曰：“傷人乎？”不問馬。

When the stables were burnt down, on returning from court, Confucius said, "Was anyone hurt?" He did not ask about the horses.

Analects X.11, tr. A. Waley

Here on the linguistic surface, the Chinese symbol system is picture based and requires that the speakers memorize thousands of individual symbols in order to calculate meaning in this system of communication.

Alphabet systems of writing use a more mathematically-based approach to writing that incorporates abstraction into the symbolic representation of the language. Standardized symbols are used to represent the sound patterns that make up words instead of using a different symbol for each individual word. Calculations are then done according to some basic underlying rules for combining the symbols. This greatly simplifies the mental "arithmetic" required to record and deliver the message.

Arabic script represents such a shift from symbols that represent words (as in Chinese), to symbols that represent components of words. The number of symbols is limited to specific sound "values," which can then be combined in different ways to produce thousands of different words.

English represents an even more precise set of symbols that enable a greater level of specificity and precision in communication with an expanded vowel system. English enables speakers to produce a more exact picture of what they want to say and allows less room for the reader to misinterpret what is being said. Here is a comparison of English with Arabic, where vowel usage differs:

bank	بأنك	بنك
ك ن أ ب	knab	knb

English provides an expanded level of specificity—bank, bonk, bunk—whereas in Arabic all of these are written as "bnk." This is the same kind of linguistic expansion needed to better calibrate social values.

As for the agent-based methods, we have a new understanding of complex systems, but no standardized ways to broadly apply that knowledge to social problem-solving. John Collins, a professor in the department of Computer Science at the University of Minnesota, spoke of the primary advantage of Multi Agent Simulations: "Agent systems can be very reactive to new events, whereas O.R. methods

may need too much time to recalculate an entire solution when a sudden change occurs." But he also points out the main limitation: "You cannot precisely control what is happening in a MAS, because agents make their own choices at runtime. Besides, emergent behavior may occur that is unexpected for the business in which the MAS is operating, which could cause troubles." Haizhen Zhang, a researcher at Microsoft, said, "It is hard to actually build a MAS framework; creating the foundations is difficult. Many of those frameworks are developed by different researchers. But it is hard to generalize those formal frameworks into different scenarios for useful applications" (Ketter and Srour 2009).

Here again we find ourselves dealing with concepts that fall within the domain of fundamental math. Along with calibration and expansion of detailed analysis, establishing generality is also an Arithmetic level operation. In layman's terms, what we see happening in the tradeoff between OR methods of optimization and Multi Agent Simulations is essentially a tug-o-war between hierarchical, centralized control of decisions and more localized, autonomous control of decisions. What's needed is a means of bridging between the two. Ketter and Srour explain:

> The future of both O.R. and Multi Agent Simulations lies in the ability of the two methodologies to communicate with each other. There is a need for more natural and smoother integration of both techniques. How can the handoff from an optimal solution to a MAS implementation be orchestrated? ...How can the emergent behavior of the MAS be monitored and fed back into the optimization? These are questions that await a new generation of interdisciplinary researchers. (Ketter and Srour 2009)

This is where a linguistic framework such as Basic Social Math is needed to serve as the basis of calculation that can produce meaningful "communication." Here we have two areas of high-level math used for industrial systems engineering, but no common, standardized foundation to connect them. Without standardization at this underlying level, our attempts to operate in complex environments will resemble those of the Saudi student in the writing sample above, where calculations in the new context are based on rules of an old context, resulting in an incoherent picture on the surface.

In the classroom context, the same struggle between the optimal outcome and agent-based control plays out on a daily basis. Each class is made up of intelligent agents that act autonomously, yet they must still reach the targets of the course. The teacher must, therefore, engineer an environment where students can make choices, but also get feedback that allows them to make adjustments when failure is eminent. Operationally, the teacher must strike an appropriate balance between 'optimal learning' of target skills, which may mean taking control away from students, and agent-based, learner autonomy, which may mean students take control and make mistakes that cause them not to learn the target skills. Indeed, many students fail to do so and are required to repeat courses.

At Yamamah University, we have explicitly stated that the students' needs come first. As a principle of classroom management, we are not using the traditional, teacher-centered approach. However, as with the example of the Saudi student's writing, this is something easier said than done. In order for teachers to perform the necessary calculations to operate in this way, they must overcome the same challenge of generalizing as mentioned above, because no two groups of students are the same and, as we will see

shortly, the basis of these calculations is, to a large degree, culturally subjective. So we must begin with the relevant empirical patterns in the complex system that can actually be generalized in order to correctly enable the use of math in solving real-world, social problems.

The same challenge can be seen in the broader community of Academic Operations Research. In the February 2008 issue of *ORMS Today*, Gerry Feigin, a partner at Analytics Operation Engineering and adjunct professor at Columbia Business School, pointed out that an "institutionalized bias has led to a situation in which O.R. has marginalized itself by focusing far too much on rather narrow and abstract mathematical issues and not enough on a careful empirical examination of the problems that industries and governments are facing today.

A critical part of this empirical examination is doing a rigorous assessment of the importance of the problems industries face and the impact of their solutions" (Feigin 2008). To do this sort of practical assessment, we'll look at issues of classroom management through the empirical lens of neuroscience rather than through existing economic theories or cultural frames. We will evaluate events based on their neurobiological, emotional, and social consequences, not based on our assumptions or calculations from previous contexts (ergo the student writing sample above).

In other words, we do not want to "freeze reality" and make operational decisions based on rules of a past encounter. Instead, we want to identify the dynamic processes that individual agents use to function and conduct an empirical examination to find out what patterns can actually be generalized for calculations in real time. This is not focused on obscurities that are only interesting to academics or neuroscientists in laboratories. Rather, it's an effort to dig into the real problems of an operating classroom in ways that follow the advice of Cambridge's Dénes Szűcs and Usha Goswami who urged that neuroscientists should not work in isolation. "Educational researchers and teachers, with their extensive practical experience, need to be involved in formulating research questions. Their practical knowledge should also contribute to setting strategic directions for educational neuroscience research" (2007).

It is from my own practical experience in business operations and insurance that my work in identifying decision patterns and operational cycles began. Long before I ever entered a classroom as a teacher, I had studied and written about the cyclical relationship of what I termed the Elements of Choice. Drawing on my practical knowledge of insurance underwriting, I identified four key variables in the general decision cycle and four binary (yes/no) connections between these variables as shown below. I labeled the variables as, Desire, Decision, Action, and Result. The binaries I labeled as Knowledge, Responsibility, Reality, and Experience (Hanson 2002).

In underwriting, behavior patterns and decisions are evaluated for their probabilities of producing financial losses to an insurance company. My approach was to reformulate these principles of risk assessment from the perspective of individuals, so they could avoid losses. In other words, I wanted to give the individual agents better ways to manage their own decisions based on the mathematical knowledge and experience of insurance underwriting.

After I identified the key patterns and relationships of the general decision cycle, then I began to uncover the problems caused by culture and linguistics. Four years after publishing my work on the elements of choice, I began the graduate course for which this paper is being written. It was then that I was introduced to the early work of John Dewey and Jean Piaget, and the later work of David A. Kolb and Roger Fry (1975), on what is now known as the Experiential Learning Cycle, shown here:
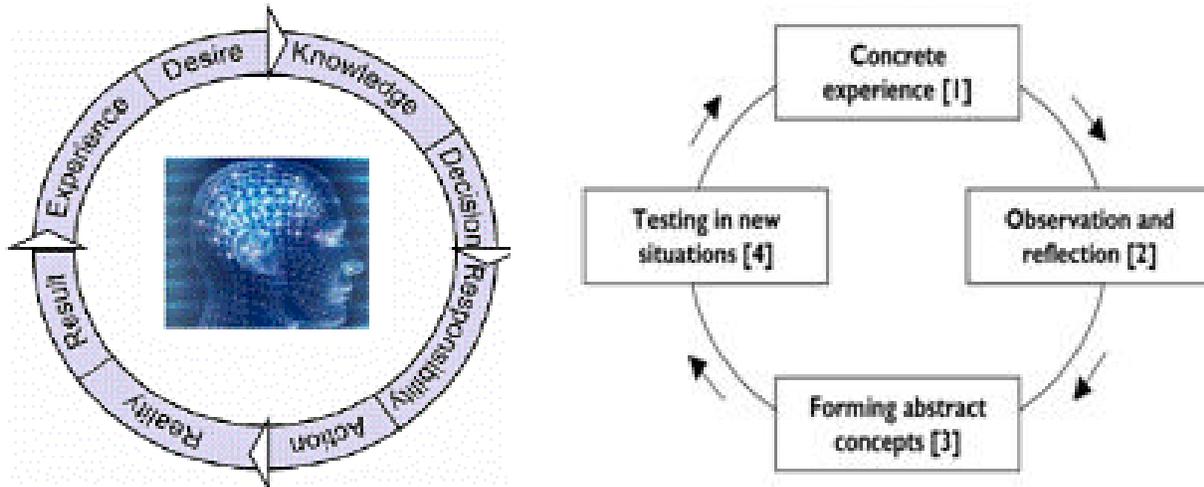
I immediately recognized the parallels between the two models and, upon closer examination, I realized that they both represented the same underlying psychological process. The only real difference between them was linguistic, that is to say, we were all talking about the same underlying process, but giving it different names. I also found this happening between other disciplines. Here are two more examples of the same cycle.

The first is the Military Decision Cycle from a presentation made by Gert-Jan de Vreede of the University of Nebraska – Omaha at the 2009 meeting of the Canadian Operations Research Society and INFORMS. The second is from a presentation by Maciek Kolodziejczak of the UCLA School of Public Affairs (2005).
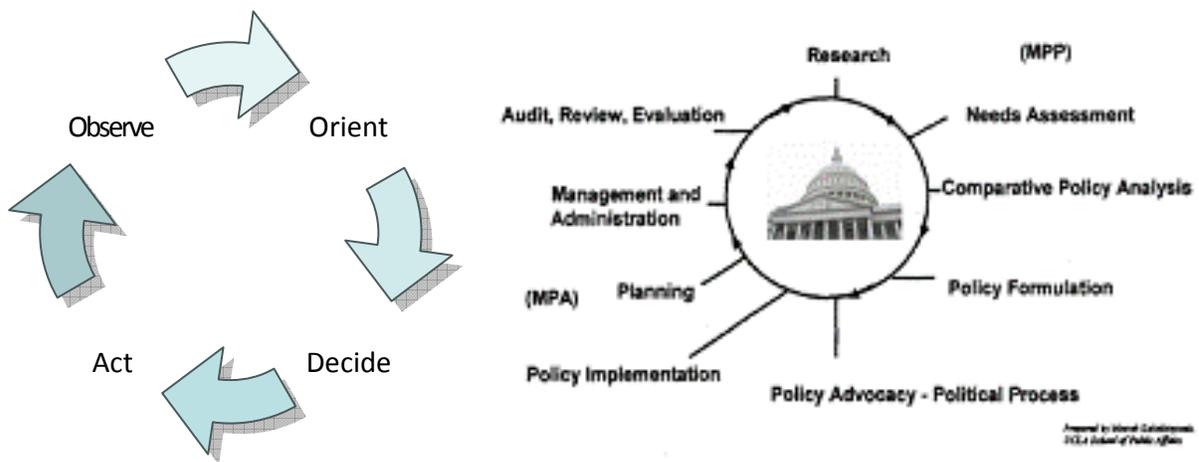
Here again, we see different terms for essentially the same underlying psychological process. The patterns we find in this cycle are precisely what we need to help us solve some of our mathematical problems. But to do so, we first have to recognize and solve this problem with linguistics. Hence we have an interdisciplinary problem on our hands that neither discipline alone can solve. Correctly identifying the cycle gives us an empirical system that we can use as the basis of reference and calibration, like using the freezing and boiling points of water in temperature scales. But to keep track of the exact similarities and differences we need a more rigorous linguistic frame.

With Arithmetic's help, we are going to expand our ability to identify and calibrate data for decision analysis so we can eliminate this naming problem and more accurately calculate values. Although decisions may vary in size, direction, and scale of operation, if the underlying cycle never changes, then we can use it to establish generality, synchronize operational values, and decode the complexity of interactions.

This leads us to some interesting questions:

If this cycle is the same across disciplines, is it also the same across cultures?

Is this linguistic problem the cause of math's dysfunctionality in the social sciences?

As we explore the state of social science in more detail, we see that studies have largely been left to non-mathematical approaches that use verbal theories to map out and explain the relationship dynamics observed. As we see in the examples above, this creates a host of linguistic problems that complicate both the analysis of observations and the conclusions we reach, as in the case of David Brooks and the complexity in human affairs. Verbal approaches also limit our ability to use the powerful problem-solving tools that have fostered so much innovation in the physical and biological sciences.

Chapter 3: Purpose

In this chapter I will attempt to show how we can use mathematical concepts and tools to help bridge the gap between the physical and social sciences. We need more robust linguistic tools in order to map out this territory with greater clarity and accuracy. We need to be able to pierce the complexity and identify key patterns that can serve as the common ground that unites all the social sciences.

It may sound a bit complicated at first, but the idea behind Basic Social Math is relatively simple; it seeks to apply mathematical standards to calculations involving social values. Rather than using cultural frames, it uses core emotions and the empirical processes of neural network formation (processes connected to learning and decision making) to create alignment in the value structure it employs. As neuroscience opens a new window into the functions of the brain, we are seeing more clearly that this organ is calculating value all the time.

> As Steven Quartz of the California Institute of Technology said during a recent discussion of ethics sponsored by the John Templeton Foundation, "Our brain is computing value at every fraction of a second. Everything that we look at, we form an implicit preference. Some of those make it into our awareness; some of them remain at the level of our unconscious, but ... what our brain is for, what our brain has evolved for, is to find what is of value in our environment." (Brooks 2009)

The basis of these calculations in social situations is largely cultural, meaning that it is greatly dependent upon the developmental trajectory of the individual. Gary Weaver at the School of International Service in the American University explains, "This part of culture is learned unconsciously simply by growing up in a particular community or family. No parent sits down at the breakfast table with a child and teaches a lesson on 'cultural values.' Rather they are learned unconsciously just by growing up in a particular family. This is the reason we are relatively unaware of our cultural values until we leave our country and interact with people of other cultures" (Weaver 2008).

Observers from different cultures often create vastly different evaluations of the same set of interactions because they are calculating different factors with different values that are not mathematically consistent. They reach conflicting conclusions that still appear to be coherent, because their respective linguistic frames do not provide the mathematical rigor necessary to detect the inconsistency. Since each observer's conclusion appears to be coherent, the result is seemingly irreconcilable conflict. As Dr. Weaver said, it's a problem that goes unnoticed until observers actually move outside their own culture and experience operations in another. Here is an easy visual example from a Chinese artist that I met in Xi'an who painted a portrait of me, an American:

Chinese Artist   Artist's Portrait   Digital Photograph
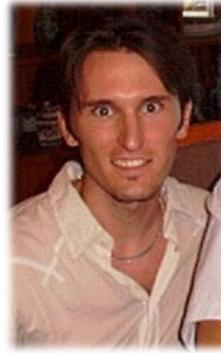
We can also see how this happens by looking at a less complex example from linguistics. For an Arabic speaker learning English, the letter combination *ai*, in the word *rain*, represents the same kind of problem. In Arabic, the speaker will match these letters to أ (alif) and ي (yah) respectively. This creates a problem because the way the sound "values" of these symbols operate in the complex system of Arabic does not exactly match the way they operate in the complex system of English (i.e., *a* ≠ أ and *i* ≠ ي in every case). In Arabic, the combination produces the English diphthong in the word, *try*. So, Arabic speakers will mispronounce the word *rain* as *Rhine*, and they will misspell the word *try* as *tray*.

As we move up the scale in complexity from letter combinations to word combinations, again we find the same problem that causes miscalculation and confusion. In Arabic, the adjective follows the noun it describes. So, Arabic speakers might say something like "a bank investment" when they mean "an investment bank." To the speaker of Arabic, the first statement seems perfectly coherent, but a native speaker of English would think that the Arabic speaker was referring to a type of investment, not a type of bank. These types of problems cannot be solved by the application of statistics, which is the most common way to use math in social science. They are arithmetic problems at the fundamental level of the complex systems of language.

In order to resolve such conflicts as we move back up the scale in complexity from language to decision making in social operations, Basic Social Math seeks to provide an alternative approach to the mental processing of information. It does not use cultural values as the basis of calculation, for example, where Arab students might calculate one way and their American teacher another. Instead, it seeks to formalize non-number values that are based on the general dynamics of decision making and

core emotions, or what has been described as our "emotional rudder" (Immordino-Yang and Damasio 2007). Decision constraints and priorities are directly connected to the non-linear cycle of learning that is universal to neural network formation and thereby culturally neutral. "A relatively new idea in science is that the brain controls behavior and behavior in much the same way impacts the brain," said Dr. Kim L. Huhman, a Professor of Psychology and member of the Behavioral Neuroscience Program at Georgia
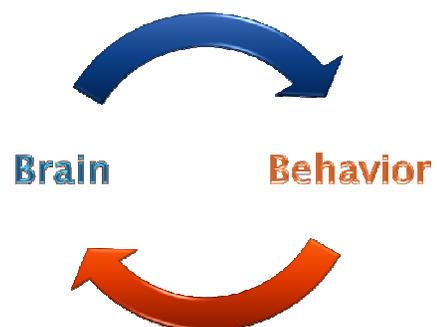
State University (Huhman 2005). The cyclical nature of this process must be taken into account in order for any analytical approach to be usable. Within this empirical framework of observation, it then applies the more rigorous quantitative methods of basic math to the same calculations in order to eliminate the confusion generated by different modes of linguistic processing as shown above. A fundamental realignment can provide the basis for correcting the foundational errors in current economic and decision theories by accurately modeling the underlying process. From there, we must rebuild the entire framework of calculation based on the empirics of this non-linear cycle rather than on traditional linear constructs.

In the August 2009 issue of *ORMS Today*, Robert F. Bordley, a Technical Fellow at the General Motors Corporation, explained more about how to make decision analysis more accessible by transforming numerical representations into visual diagrams that maintain the underlying structure that is technically robust. He redefines the traditional decision analytic expected utility function as the probability of attaining some goal, where the decision-maker is uncertain, not only of the consequences of any decision, but also about what is required to achieve the goal. He replaces the conventional arc and node representation of decision trees with a series of adjacent shaded blocks where the relative height of a block represents relative probability along with shading that represents positive or negative outcomes associated with each block. "Thus a student can construct, quantify and solve a decision tree without numbers," he concludes. "This approach complements the quantitative methods in the same way that elementary school physics classes complement college physics classes" (Bordley 2009). This is the same kind of conceptual bridge that Basic Social Math seeks to broaden and solidify across the social sciences in order to correct problems and make tools more accessible to law-makers, executives, and educators in diverse disciplines.

Questions of balance in systemic operations are resolved based on standards of math and empirical observations, not cultural norms or group opinions. Such an approach produces a more accurate calculator in the brain; one that can be synchronized easily with others regardless of cultural variation. The shift in data processing is like switching from an analogue system to a digital one, like moving from the Chinese artist's portrait to a digital picture. Its development and implementation represent a critical first step towards systemic innovation in the social sciences.

Upgrading the brain's calculator with Basic Social Math does not force everyone to see things from a single point of view. It doesn't force my Saudi students to reject their own views and accept everything from my American perspective in order to reach an agreement about what we observe. To the contrary, it provides a framework by which all observers reconcile outcomes using the same constellations of emotions that underpin the complex social interactions in question. It's not about forcing everyone to use the same values, but it's about synchronizing values based on empirical points of reference. It first seeks to create linguistic alignment so that people are measuring social factors in a standardized way and that their calculations preserve magnitude and scale with mathematical consistency.

Remember, we are looking for ways to improve calibration and the level of detail in order to move seamlessly between small and large scales and to achieve the best possible outcome within the local operating conditions.

If we think back to the complex system of primary colors and works of art, and compare the outcome of painting portraits to the outcome of learning, then we see there are many ways to achieve the desired result. Math does not force everyone to paint the same picture, but it does affect the level of clarity, accuracy, and quality in the final product. Incorporating the fundamental tools of math into the process opens doors to technical innovation, which is the difference between the Chinese artist's portrait of me and the digital picture above.

Also keep in mind, it was the "mathematical knowledge for teaching" that distinguished more effective teachers from less effective ones (Grossman 2009). Thus, a math upgrade can help the brain calculate values and solve operational problems more accurately and transparently.

> The reality is that operations research is a form of mathematics. While problem solving is a vast topic, it turns out that the mathematical tools employed to solve most quantitative business problems aren't as numerous as might be imagined. (Boyd 2007)

Rather than trying to sort out all the differences between subjective cultural frames, Basic Social Math simply reconciles all calculations to a single set of empirical factors that are not culture-dependent. That way the conclusions we reach can be independently verified and validated. Such a framework allows everyone to integrate diverse points of view in ways that create a more accurate picture for all to see, rather than creating conflicting views of the same picture. Here is where a new linguistic frame must be used to create a picture based on empirical components. The rigors of fundamental math are needed to map out the territory in a new, more objective way—think digital pic vs. artist's portrait.

This is now possible because fields like Neuroscience and Complex Dynamics in Math are helping to establish a clear and objective view of the entire context of interaction that extends from the microscopic processes inside the brain all the way up to the macroscopic processes of global economics and public policy.

In order to better engineer our social environments, we must first seek to penetrate the complexity of these systems to get a clear view of the general and universal dynamics involved. This would take us through the same steps as we went through to identify the key factors in aerodynamics that produce flight. Having a clear view of the general dynamics allows us to develop more effective technical applications, like jets, helicopters, and gliders. To clarify our view of social dynamics, we must explore ideas at the crossroads of several disciplines including, but not limited to, Public Policy, Neuroscience, Mathematics, Linguistics, Economics, and Psychology.

Microscopic   Operational Context   Macroscopic

Chapter 4: Rationale

In this chapter I will discuss the rationale for pursuing a more robust framework of analysis for research involving social dynamics. In 2006, the US National Science Foundation convened a workshop entitled "Grand Challenges of Mind and Brain—Strategies and Directions for Future Research." This workshop brought together scholars and scientists from various disciplines at major universities across America to identify key domains for research. The following was one of several areas identified to be of interest:

> One of the greatest threats facing the world today is the conflict between people. In spite of the importance of this problem, the cognitive and neural systems underlying when and how we cooperate or engage in conflict are poorly understood…. An integrated scientific understanding of competing emotional systems as they guide behavior could well lead to new concepts to facilitate cooperation between individuals, and perhaps societies as a result of conflict reduction. (Blumstein, Sheila, et al 2006)

Research in Basic Social Math begins with the biology and the core emotions that we all have in common and seeks to clear up a few misconceptions about how the brain functions in social contexts. It examines more closely the intersection of the physical and social sciences; the place where our neurobiology literally connects to our emotion and cognition.

In 2007, Mary Helen Immordino-Yang and Antonio Damasio of the Brain and Creativity Institute at the University of Southern California published some of their work entitled, "We Feel, Therefore We Learn." They explain the key role that our emotional systems play in how the brain processes information from social interactions.

> Modern biology reveals humans to be fundamentally emotional and social creatures. And yet those of us in the field of education often fail to consider that the high-level cognitive skills taught in schools, including reasoning, decision making, and processes related to language, reading, and mathematics, do not function as rational, disembodied systems, somehow influenced by but detached from emotion and the body. Instead, these crowning evolutionary achievements are grounded in a long history of emotional functions, themselves deeply grounded in humble homeostatic beginnings. (Immordino-Yang and Damasio 2007)

They go on to explain the nested relationships between higher cognitive functions of the brain and the underlying emotional systems. They show how emotional undercurrents serve as the basis of effective social functioning. This alone challenges the widely held view that social decisions should be based on rational thinking alone, and that emotions should be blocked out of the process. However, the evidence emerging from neuroscience indicates that our emotions provide a critical basis for the brain's

calculation of data from social interactions. Without this "emotional rudder," the brain may reach perfectly rational conclusions leading to actions that produce perfectly disastrous social consequences.

This shift causes a global realignment in how we view and explain social interactions generally. The magnitude of such a shift rivals the shift from believing the Earth to be the center of our universe to the Earth being one small planet revolving around a single star within a much larger galaxy.

In a recent *NY Times* article, comments by Benedict Carey help us to understand how we got to this state:

> Artists and writers have led the exploration of identity, consciousness and memory for centuries. Yet even as scientists sent men to the moon and spacecraft to Saturn and submarines to the ocean floor, the instrument responsible for such feats, the human mind, remained almost entirely dark, a vast and mostly uncharted universe as mysterious as the New World was to explorers of the past. (Carey 2009)

In a new journal, *Mind Brain and Education*, Dénes Szűcs and Usha Goswami at the University of Cambridge's Centre for Neuroscience, explained what is needed in order to tap into the new knowledge that is emerging from neuroscientific studies:

> What we really need is a new colony of interdisciplinary researchers trained both in cognitive neuroscience and in education and a new theoretical framework based around mental representation that takes into account the concerns of both educators and neuroscientists. (Szucs and Goswami 2007)

Using neurobiological evidence to clarify our view of the relationship dynamics in our mental processes helps us get a clearer view of the key patterns in the complex systems of the mind. This eliminates a lot of irrelevant possibilities that overcomplicate the picture we see from cultural perspectives alone. As we peer down the microscope of neuroscience, we begin to see for the first time how the brain's bio-electronics actually connect to the emotions and cognition that give rise to human consciousness. We find universal constellations of emotional markers that can be used like the invisible forces of electro-magnetism to keep our bearings and create alignment within complex social interactions.
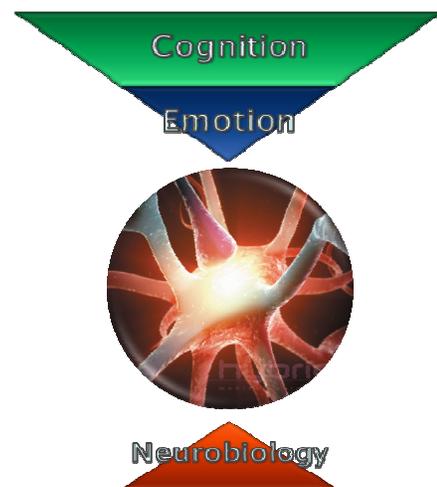
> 'That's one of the wonderful and mysterious things about the brain,' says Karl Deisseroth, MD, PhD, assistant professor of bioengineering and of psychiatry and behavioral sciences [at Stanford]. 'All these thoughts and emotions are electrical patterns flowing through the brain in specific ways.' He says talking about memories stimulates electrical activity in the brain. 'Those patterns do real things and can cause lasting changes to the brain.' (Adams 2005)

This view, in turn, challenges even more beliefs about the nature of social science itself. For example, the long standing traditional view is that fields of study in social science are not really science at all. One widely shared belief was expressed by *NY Times* business writer, Steve Lohr, who said that "management is not a science, like physics, with immutable laws and testable theories." (Lohr 2009) However, what this paper aims to demonstrate is that the traditional way we approach studies in various fields of social science is not scientific. In other words, the way we approach and frame the study of management is not like the way we approach and frame physics. This is a linguistic problem, not a problem with the nature of management itself.

Speaking about the problems of group decision and negotiation at the joint meeting of the Canadian Operations Research Society, INFORMS, and GDN, Melvin F. Shakun of New York University emphasized that "with difficult negotiations, i.e., when a solution to a negotiation problem is not forthcoming, problem restructuring (reframing) is a key approach" (Shakun 2009). When we take another look at the complex interactions of management using a more rigorous linguistic frame, we can begin to identify which components vary and which components remain constant. This gives us the solid ground on which we can then test theories and uncover the immutable laws of social dynamics like we did in physics.

R. Duncan Luce, a professor of economics and cognitive science at UC Irvine who was recently awarded the National Medal of Science for his work in mathematical psychology, made the following comments regarding the state of math in social science today:

> Imagine modern electronics without basic laws of electricity and magnetism but without using complex partial differential equations. Impossible. Or math-free solid state physics. Again, impossible. Of course, mathematical behavioral science is terribly far from such an advanced state—we are similar to 16th century physics, not even 17th and later. Most of these behavioral and social science fields, with the partial exception of economics, happily go on collecting data and formulating verbal theory with nary a bow to mathematical methods other than, mostly cookbook, statistics. (Luce 2005)

In the 17th century, when Isaac Newton and Gottfried Leibniz were seeking ways to better solve problems in physics, they had to expand the framework of math at the complex end because calculus had never been developed nor validated. In social science today, we are dealing with the reverse situation. We have a lot of complex math for social analysis, but the fundamental end of that framework has not been fully developed or validated. Without the expanded framework of math, physics could not be the science it is today.

The same is true for management and the other social sciences, but the development needed is in the opposite direction of what was needed for physics. To understand why, we need to ask ourselves what it is about the linguistic frame of math that allowed us to see further into the complexity of the physical world than was possible using our natural sight alone.

Think about the major breakthroughs in physics and chemistry.

How did we begin to clarify our view of atoms and molecules that were far too tiny for our eyes to see?

How did we begin to create more accurate models of their interactions that led to so many medical and technological breakthroughs?

Was it with statistics?

Was it calculus?

Was it geometry?

Or was it something else?

The answer to these questions is found at the crossroads of math and linguistics, not statistics. Yet most mathematical research in social science today is focused on statistics and sophisticated math.

"There is a need for new computational and mathematical tools that will inform a neuroscience of inference and theory construction," stated the 'Report on Grand Challenges of Mind and Brain' from the aforementioned workshop hosted by the National Science Foundation (Blumstein, Sheila, et al 2006).

To get a sense of why we need to focus on linguistics and fundamental math, just think about how small 10^{-23} is. The ability to capture and convey minute variation is something that only arithmetic is able to do. Basic math provides the linguistic frame in which we can capture a level of detail that the word *tiny* just can't accurately convey. Furthermore, *tiny* means different things to different people in different contexts. That's the problem with relying on the verbal theories that Duncan Luce was talking about.

By beginning with the empirical context of the neurobiological systems in which emotion and cognition manifest, Basic Social Math seeks to codify and validate the body of analytical tools, methods, and principles required to map out and validate the general decision processes that underlie all social and cultural value systems. It uses the structural framework of Multi Agent Simulations to breakdown the component parts of a given system in ways that help us penetrate the complexity. This opens the door to the correct identification of how and when mathematical operations can be applied to calculations in social interactions.

Instead of trying to reconcile the calculations of one cultural frame with those of another, Basic Social Math seeks to create a new, more objective set of value markers tied directly to the empirical context that underlies social interactions. This sort of linguistic innovation can greatly simplify calculations in ways that create alignment across multiple contexts of application.

Operationally, this parallels the linguistic shift from using Roman Numerals (*i, ii, iii, iv, v, vi, vii, viii, ix, x, xi, xii…*) to using Arabic Numerals (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12…) as a means of marking and keeping track of values. Calculations based on Roman Numerals are functional, but cumbersome as the following illustrates:

$$\begin{array}{r} \text{LXXVIII} \\ -\text{XLIV} \\ \hline \end{array} \quad \text{vs.} \quad \begin{array}{r} 78 \\ -44 \\ \hline \end{array}$$

If you are using the symbol system of Roman Numerals, you will probably conclude that Arithmetic is a difficult exercise because of its lack of alignment at the linguistic level. Likewise, many have concluded that cross-cultural interactions are extremely difficult because the underlying social values do not align in consistent ways, which seems to create irreconcilable conflicts at the operational level.

We don't have to look hard to find examples of this, especially when we examine operations and relations between Middle Eastern countries and the West. It is in this larger context of social interaction that a new perspective of analysis is needed in order to reframe and resolve problems.

Hence my interest in the cross-cultural classrooms of Al Yamamah University in Riyadh, Saudi Arabia with its Western-designed educational system that is operating in the heart of the Muslim world. It was in this new hybrid context that I wanted to test how well I could use a new computational method within the real-world social dynamics of a functioning system.

I wanted to see if such calculations could avoid conflict altogether and/or how effectively they could resolve conflicts so that my operation could run smoothly within the local context and also deliver the best possible result.

To accomplish this, when I entered the graduate program for which the present paper is being written, I intentionally dropped all of my culture-based assumptions and sought to avoid using my own cultural values as a basis for any performance assessments.

Instead, I calibrated my operational approach based on the empirics of the decision and learning cycle that I spoke of earlier. From the beginning, I looked for ways to use these underlying psychological and neurobiological processes to determine the operational values, universal constraints, and decision maps that I could use to engineer learning environments in any context and under the uncertain conditions of changing dynamics.

The upgraded linguistic framework and research objectives of Basic Social Math are the result of this work.

Chapter 5: Examples

To get a better sense of how Basic Social Math can help us decode the complexity of social problems and develop innovative solutions, let's first go back to the example from the Saudi student who was trying to function in English. This time we'll take a look at his writing from the teacher's point of view and examine the problems that arise in the social interaction associated with learning.
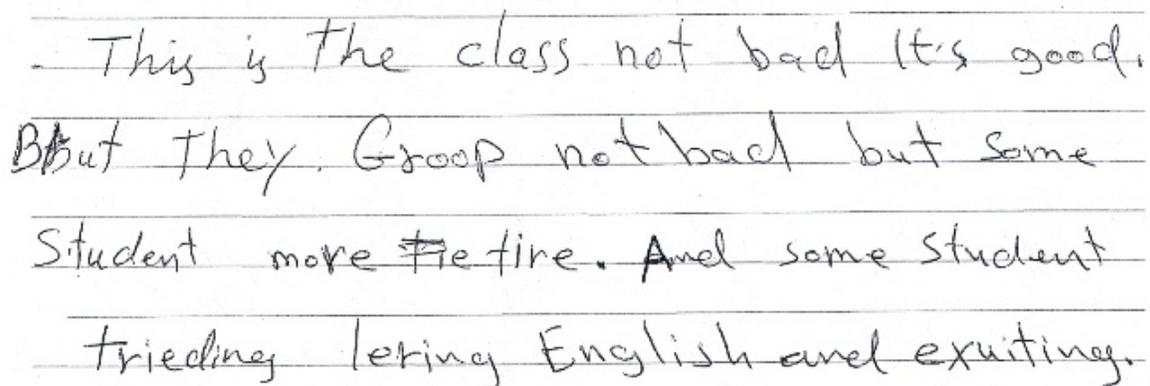
This is the class not bad It's good, BBut They. Groop not bad but some Student more the fire. And some Student trieding lering English and exuiting.

From a very practical point of view as a teacher, what do you actually do with this student?

Do you tell him about the rules for Present Continuous, Past Participles, and Predicate Adjectives?

If so, in what language do you explain these things to him?

Once you explain, does that mean he now can write in ways that speakers of English will understand?

As we ask these questions, we quickly discover that knowing how to communicate in English is not the same as knowing how to navigate the complex social interaction that will help another adult learn how to communicate in English. The most natural response to this situation is to do operationally the exact same thing that this student did linguistically.

You think to yourself, "Back home in the United States, whenever I wrote something in English class, I gave it to my teacher to correct. She circled the mistakes and gave it back to me. That worked well." So, you circle all the mistakes and hand it back to the Saudi student. Everything seems fine until the student hands you his next piece of writing. The words are different, but they are still out of place in similar ways to what you see above. You circle all the errors again, and hand it back to him. You repeat this several times, but little changes. Frustration sets in because nothing seems to make sense. What worked fine back home, isn't working in your new context of operation.

Remember the 80/20 split from the physiology studies of the brain? Most of the information that the brain uses to create a mental picture of social landscapes is coming from memory. External changes don't automatically change internal maps. The following illustration gives an example of what it's like for both students and teacher to operate in a rapidly changing environment. Think about what happens operationally when your internal map no longer matches the external landscape as illustrated here:

In this situation, the difficult thing to comprehend is that, to the student, your operation may look as incoherent to him as his writing looks to you. The hardest part is fixing problems in your mind, not his. In both cases, the problems come from trying to operate in a new complex system based on the rules and methods of a previous context. Essentially, what we need is to bring coherence to our decision making in the complex operation of the class in the same way that we establish coherence in language. But this is not possible by simply using the grammar and structure of Arabic with English words on the surface. Likewise, it is not possible to operate coherently by simply using cultural values from one context as the basis for decisions in another. Sorting out all the variations at the surface level is difficult even when interactions are simple. When they get more complex, making sense of things can seem impossible.

So when we look out over the vast oceans of culture and human diversity, it's easy to conclude that the differences are simply too great to be bridged or crossed. If we want to talk about economics, for example, we cannot speak in general terms because we have to consider the culture in which the economy is operating. Are we talking about economics under Communism, Islam, or American Capitalism? If we talk about psychology or education, we also have to consider the cultural context. On the surface, this cultural subjectivity appears to create a great deal of variation within and across social science disciplines because each one is framed in a different cultural 'color.'

This is where we have to go back to Agent-based Models and the structure they help us identify in complex systems. Remember, an incredible amount of complexity can be produced from a few simple underlying components.

The question is this: How do we decode the complexity that we see in culture and language? The answer can be found in the same apple that got Isaac Newton thinking about gravity.

As we probe from the cultural surface down to the language then to the empirical context, we see a lot of variation.

Economics	Psychology	Education	Economics	Psychology	Education	Economics	Psychology	Education
Communist Culture			Islamic Culture			American Culture		

ябълка   تفاحة   apple

Visually, the words here all look very different, but deeper down at the linguistic core they are actually all the same. So, to decode the complexity, we have to reach down to the level of the apple. The only problem with this has been that we couldn't ever see the apple. But now, the microscope of neuroscience is giving us a way to change all of that. David J. Farmer of the Wilder School of Government and Public Affairs at Virginia Commonwealth University said it this way:

> Neuroscience promises to act as a catalyst, in the longer run, in seeking re-unification of the fragmented social sciences (e.g., political science and economics) and social action subjects (e.g., public administration and business administration) that concern governance. Neuroscience can achieve this because it reveals that taken-for-granted concepts, and the language used to express them, should be challenged. (Farmer 2007)

Ok, that sounds great, but how? Here again, language gives us clues to how it happens. When students are beginning to become functional, they often try to translate phrases from their first language to descibe situations they encounter. During class, one student said to me, "He threw his face in." Huh? "What does that mean," I questioned. He explained that another student was interupting a conversation that he wasn't a part of. "Oh," I said. "He stuck is nose in." In order to translate effectively, we can't just change the words on the surface, we have to go down to the emotional core and then reconstruct the phrase within the constraints of the second language. So, to operate coherently in the complex system of the class, we have to do the same thing. And this is where neuroscientific studies are helping us see more clearly the fundamental relationships that underlie complex systems of social interaction. In their article, "We Feel, Therefore We Learn," Imordino-Yang and Damasio cited case studies done with patients who had suffered damage to the part of the brain that is connected to our emotional systems:

In retrospect, these patients provided a first glimpse into the fundamental role of emotion in reasoning and decision making. Missing a brain region that is now understood as needed to trigger a cascade of neurological and somatic events that together comprise a social emotion, such as embarrassment, compassion, envy, or admiration, their social behavior suffered. This is significant in itself, but even more intriguing was the realization that, without the ability to adequately access the guiding intuitions that accrue through emotional learning and social feedback, decision making and rational thought became compromised, as did learning from their mistakes and successes. While these patients can reason logically and ethically about standard cognitive and social problems in a laboratory setting (Saver & Damasio, 1991), out in the real world and in real time, they cannot use emotional information to decide between alternative courses of action. They can no longer adequately consider previous rewards and punishments or successes and failures, nor do they notice others' praise or disapproval. These patients have lost their ability to analyze events for their emotional consequences and to tag memories of these events accordingly. Their emotions are dissociated from their rational thought, resulting in compromised reason, decision making, and learning. (2007)

In another case, they cite work done with children who had similar brain damage/defects from birth:

What these patients confirm is that the very neurobiological systems that support emotional functioning in social interactions also support decision making generally. Without adequate access to social and cultural knowledge, these children cannot use their knowledge efficaciously. As Vygotsky posited more than three quarters of a century ago, social and cultural functioning actually does underlie much of our nonsocial decision making and reasoning. (2007)

So, if we break down the structure of the complex system, we find a limited set of emotional undercurrents and a universal set of neurobiological components that interact to produce all of the complexity in human affairs. I believe these core emotional undercurrents are the 'primary colors' that the mind uses to create decision pictures which become the basis of judgment in social interaction. Although we currently name the components of these systems differently across different cultures and disciplines, they are all actually the same. So, combined with the decision and learning cycle, what I was interested in determining was whether these empirical components could provide the 'apple' that we need to decode
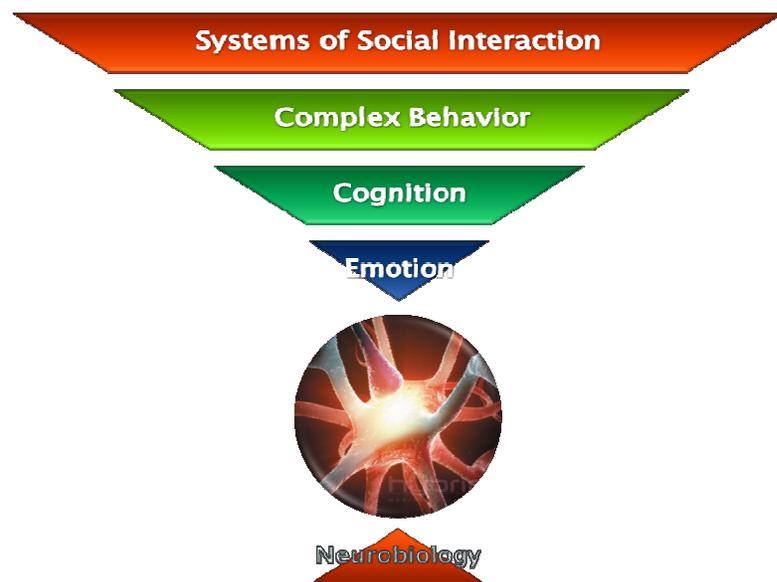
the complexity in human affairs? By reframing in these terms, can we now establish the mathematical basis for alignment and reconciliation between cultural value-sets? This is what I wanted to test and validate from an operational point of view in the cross-cultural classrooms of Yamamah University.

The classroom is a good laboratory to experiment with this, because it is a very dynamic environment. In addition to the cultural changes, each group of students creates unique operating challenges. Where one group can be studious and eager, another will be unmotivated and resistant. As a teacher, I have to be able to respond and adapt to changes in order to facilitate learning no matter how dynamics may shift and especially in the most difficult cases (which is what I was interested in most). For the past three academic years, I've been able to observe and work around these changes every two months.

I've already mentioned that one of our stated principles of management is that the needs of student learning take priority over the traditional teacher-centered approach. This means that I am not supposed to force my operational values as the teacher onto the students. This practical knowledge is the cornerstone of Caleb Gategno's *Silent Way*. "Teaching," he said, "is subordinate to learning." But that is easier said than done; especially if my experience comes from operating in a traditional context. My attempts to function in this new way are likely to resemble those of my students trying to write. Worse still, it will be extremely difficult for me to see the mistakes I'm making in the interactions.

Beyond the mechanics of teaching and learning, the class is also a business operation. I am providing a service that students pay money for. So, I also have to consider things from a customer service perspective. Does this mean that the customer is always right? Is it a case of anything goes for the students, since their needs come first? What constrains the decisions we make individually and collectively in the day to day functions of the class? How do I balance and integrate the values of teaching with the values of customer service to produce a coherent and productive operation?

As the questions multiply, the complexity of the operation becomes apparent. Again, we need to consider what tools of math are useful in solving such problems? How do we actually do these kinds of social calculations? How do we optimize the outcome of learning (OR)? How do we adapt to changes in the local operating conditions (MAS)? Do we need a sophisticated algorithm and statistical model to solve such problems? What kind of math do we use in mapping and navigation?

What I found in the Saudi classroom was that, more than anything, I needed the students' help in order to navigate their social context successfully. In the traditional hierarchy, the assumption is that the person who is older (the teacher) will have better maps stored in that 80% we use to create navigational pictures. But when the landscape has changed, this may not be true and could create more problems than it solves. If students get lost, I lose credibility as a leader. Also, if I don't forcefully assert my authority, they might conclude that I am a weak teacher and do whatever they want to pass the time.

My first test came when I inherited a class of students with low level writing skills. Some of them had repeated the same level 4 and 5 times in a row. One major problem was that the leader of the group had also spent 18 months in one level. By the second week, everyone felt comfortable, too comfortable. So, I had to do something drastic to flip the dynamics of success and failure. This student sat chatting with his neighbor in Arabic, so I handed him the papers we were working on and asked him to stand up. I sat down in his chair and waited for him to do what he was good at—lead.

 At first, the other students were in shock. Then, they had to decide whether or not they were going to learn English that day. This forced everyone to decide collectively what was valuable. They chose English and started working.

This approach worked so well, that I made it a regular part of our classroom structure. Even the lowest performing students would suddenly come to life when the relationship dynamics were flipped around in this teacher/student role reversal. All the disruptive behavior that was directed at me before suddenly became the student's problem to deal with.

The students pictured below are an example of one such incident. The one on the left was acting as the teacher, when the one on the right began popping his bubblegum loudly. The teacher knew exactly what to do to deal with his peer. This was a social game he had played before. Since I was just one of the other students, I didn't have to be the bad guy or make any threats of punishment. We all had a good laugh and simply moved on.

However, in order to navigate potentially volatile situations like this, I have to thoroughly understand the underlying process of learning so I can realign the dynamics to produce the results we want. I have to know what will actually propel students through the cycle versus what will merely further my agenda as a teacher. This requires a shift in my decision-making priorities. I have to recognize the difference between engineering an interaction around *fear* versus *pride*. These invisible mechanics, which operate under the surface, hold the keys to solving social problems in creative new ways.

In order to empower both students and teachers in this type of problem solving, we must first bring these invisible mechanics, priorities, and values into clear view so we can validate causal relationships and keep track of all the variables. This is where we need the help of basic math because it's not something that natural language is very well equipped to do.

As Patrick Noonan of Goizueta Business School at Emory University put it, "…evolution has molded our 'human operating system' to solve problems quickly, robustly, with little information…but only approximately. Worse, our internal rules of thumb lead to common decision traps. It is easy to show that we are not wired to solve the sorts of problems our stakeholders now demand of us, and that we need additional, analytical methods to fortify our natural skills." (Noonan 2007)

I've given just a few of the practical problems to which Basic Social Math can be applied, but I haven't explained how the framework of math can help us see the incoherence of our own decision making in complex systems. Next, I'll discuss how math can help us recognize flaws in the operational structures we employ to reach different objectives. To do this, we'll focus on the specific challenges that a teacher faces in structuring a learning environment in the classroom.

Chapter 6: Applications

The primary area of application for Basic Social Math is in the problems of decision making in complex social interactions. As illustrated in the examples of the previous chapter, the subsurface mechanics that are largely invisible require a more rigorous linguistic frame to bring the dynamics of problems into clear view for objective analysis. Just as the Saudi student has extreme difficulty seeing anything wrong with his writing, so too do we teachers and administrators have difficulty seeing our own operational incoherence. This is where the more rigorous frameworks of math can help us see the flaws in our methods of problem solving and in our approach to engineering in social environments. Math gives us better tools to begin deconstructing the components of our operating system so we can evaluate how well they produce the results we want to achieve within changing environments like a classroom.

Here's one representation of common practice as it relates to how we engineer learning environments.

Come on Time ➕ Do Class Work ➕ Don't Cheat ➕ Do Home Work ＝ Learning

But is this an accurate model of the underlying components of learning? Is it coherent?

Action ➕ Action ➕ Action ➕ Action ＝ Learning ?

This is just variation in a single variable, but learning is a complex, multi-variable process. If this is what we think constitutes learning, in other words if our internal map is linear, then we are easily mislead to believe that learning can't happen without these factors.

Come on Time ➕ Do Class Work ➕ Don't Cheat ➕ Do Home Work ≠ Learning

In the real world, learning can still happen without doing any of these actions. So if we use this as a basis for our decision calculations in the social interactions of the class, then we are likely to create conflicts with students. If our thinking is linear, then our decision maps will not accurately match the actual dynamics of learning, which will cause confusion for students. We will be inclined to make operational decisions that may in fact obstruct learning.

For instance, just because a student didn't come on time, doesn't mean s/he didn't learn anything. Yet how often to we find ourselves trying to control such behavior by creating additional negative consequences for the student? Conversely, just because a student **did** come on time, doesn't mean s/he learned anything either. So, already we can see how basic math is helping bring our assumptions into better view so we can start dealing with these decision traps. It provides a way for us to probe and question the logic behind our approach to solving problems.

Another structural problem becomes apparent when we compare this *Linear Model* to *Communication* in general. Before we even get into any of the issues of specific values, here we can easily see that this linear construct doesn't match the structure of a complex system, because it is like saying the following:

While these may all be components of a sentence, there is more to communication than the words you see on the surface. This linear stucture doesn't match the real world interactions. Hence, if this is the basis for our operations in the complex system, then incoherence and conflict will be the results.

So, if this doesn't add up, then what kind of math does?

To answer this question, we have to go back to the decision and learning cycle that I mentioned earlier in Chapter 2. As I said before, we first have to take into account the non-linear, cyclical nature of the interaction between our behavior and the neurobiology of our brain. This multi-variable cycle provides the empirical system that is needed in order for us to identify the conditions that will enable the application of mathematical operations. Only by testing and observing the real world interactions of this cycle, can we begin to correct the errors in the application of mathematical operations in current economic and decision theories.

I don't have all the answers yet, but I have tested and observed enough to know how the key variables in this cycle interact in multiple contexts. I will attempt to illustrate and explain how using this cycle as the basis of calculations in social interactions is different than the linear constructs above.

First of all, it's a non-linear structure, where the interaction of the variables is important, not the variation. In other words, in order for learning to take place, you must cycle through all of the variables, not just one, or two, or even three. Real learning is also random and chaotic. So, it doesn't really matter where you begin or end, but that you complete the cycle.

For beginning language learners, at first the brain is overwhelmed by the complexity of the new language. Why can't it perform the calculus at this stage? Well, when we think back to the brain physiology studies, we have to remember that 80% of the information required to produce coherent pictures comes from data already inside the brain. So, it must first store a large quantity of data in its memory before it can integrate a complete picture of what it perceives. Therefore, we have to go through the experiential cycle several times before the calculus can even work. Our brain cannot process all the information in a complex system until it has stored enough data to distinguish between key patterns and simple variation. For example, recognizing that adding the "s" sound to the end of a word is a pattern that carries meaning, not just a different sound than "g."
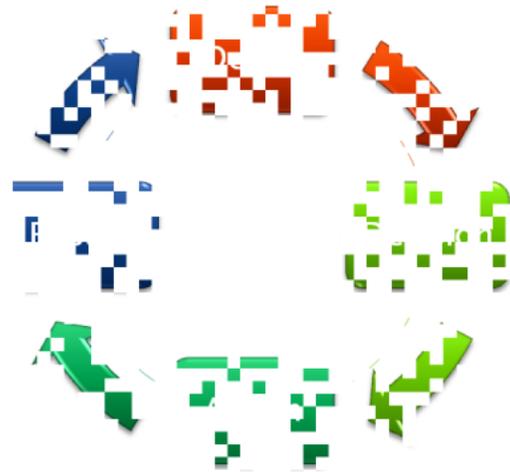
With language, there are multiple variables that interact according to specific rules in order to produce coherence. The same is true for decision making in the operations of complex social interactions. This cycle is an empirical process that establishes certain rules that produce coherence. Since the brain cannot perform the calculus without a minimum threshold of information stored inside, this constrains what actions we can take in the class. It is not a case of anything goes for the language students, because certain things must happen in order for their brains to record what is necessary for them to gain functional ability in the new complex system of their target language. If they don't do the things that produce this result, then the operation of the class will be incoherent. These constraints are not rules that I dictate as the teacher, rather they are established by the empirical components of the context itself. Hence, they are not subjective rules I impose, but fully generalizable rules for coherent decision making.

As with language learning, each time we complete the cycle, we get another piece of the puzzle that our mind then uses to calculate meaning. It's a non-linear, random process that doesn't give us the full picture at once. Rather it takes time for the brain to acquire enough of the bits and pieces in order to integrate a coherent picture. Regardless of how we name it, this empirical process gives us a way of establishing both a clear and a consistent picture of our common environmental constraints as well as the underlying rules of the complex systems in which we operate. It helps us recognize the generalizeable patterns that distinguish key variables from random variation, so that everyone can see clearly, regardless of their
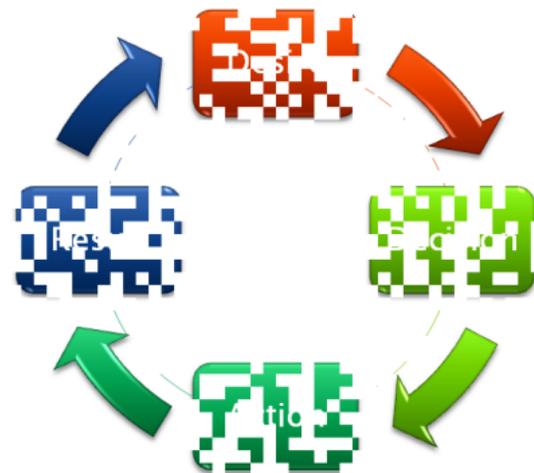
individual perspective or developmental trajectory. What is important is getting the relationships and interactions between the variables right, not worrying about all the possible variations. Development comes as the learners cycle through all the variables enough times for a clear picture of the patterns to emerge within their neural networks, which enables them to become functional in the target complex system, be it linguistic or operational.

The best way I can illustrate what this means is to compare the complex outcome of learning to the complex outcome of flight. In both cases, managing multiple variables in the right combination is what gets the "bird" off the ground!

As with flying an airplane, the interaction of invisible forces in the classroom largely determines whether or not a lesson gets off the ground and safely delivers students to their learning targets. This is a complex process that requires constant monitoring and evaluation of multiple variables to maintain control.

For a pilot, these variable components are centered on controlling airspeed and altitude. Let's examine an example of how complicated it can be to maintain control of a real airplane taken from a flight instruction book by John S. Denker:

> Generally, a pilot who tries to control airspeed and altitude separately winds up controlling one or the other rather poorly. Usually it is the airspeed that suffers. All too often, the airspeed gets too low, whereupon the wing stalls and the pilot rather abruptly loses control. This is how the all-too-common stall/spin accident begins. You can stay out of this sort of trouble if you understand what the controls *really* do.

> The key to understanding the relationship between airspeed and altitude—and several other things—is the concept of *energy*.

> Energy is not a new or complicated concept. Most pilots understand that being "high and fast" is very, very different from being "low and slow"; the concept of energy just makes this notion a little more precise and gives it an official name.

> Good pilots think about energy all the time. The more critical the situation, the more carefully they evaluate the energy before reaching for the controls.

> Once you grasp the basic concept of energy, you will be able to apply it in many ways, to many different situations. This is a big improvement over trying to figure out all possible situations one by one. Energy gives you the "big picture". (Denker 1996)

By shifting the focus to the central "energy" that is part of the fundamental process of flight, you can always figure out how to maintain control no matter how conditions fluctuate and dynamics change. This is the primary advantage of an empirical approach whether we are talking about aerodynamics or learning dynamics.

The question relevant to improving our understanding of learning dynamics likewise revolves around the fundamental "energy" of the teaching and learning relationship. If you can grasp the basic concepts in this energy exchange, then you can find the most effective ways to maneuver safely in order to reach your own, and your student's, learning targets. This energy exchange provides the basis for establishing the "mathematical knowledge for teaching" that Pam Grossman was talking about. And that brings us back to the question of how basic math can help us solve problems.

In an article in *ORMS Today*, E. A. Boyd explains more, "The fact that a common set of mathematical tools can be used to address such a wide variety of practical problems is nothing short of remarkable. Abstraction is the key, recognizing that orders arriving at a warehouse and people calling to purchase airline tickets can be described in fundamentally the same way. While the actual business problems are quite different, when abstracted they can be studied together." (Boyd 2007) Abstraction is one of the most powerful tools that math brings to the table. But in order for this tool to work, we have to make sure our abstractions are accurate.

Stereotypes are a form of abstraction, but they are problematic because they are based on cultural assumptions that may not match real world conditions. However, our neurobiology and the learning cycle are universal, not culture dependent. These can be used determine the context limits and simple rules of our complex system, and for all practical purposes, they remain constant. This means they are generalizable and can be abstracted for the purposes of problem solving.

Remember, one of the problems in Multi-Agent Simulations was that we needed a way to generalize accurately.

By using the fundamental relationships of the experiential learning cycle to orient myself, I can continuously adapt my course of action to optimize learning and minimize conflict. This enables me to make navigational decisions in real time that will help me maintain control no matter how the dynamics in my classroom change (a hybrid of MAS and OR).

Let's take another example from our flight book about using this type of empirical information to make navigational decisions in changing contexts. In this example we'll look at the problems encountered when we move from the 2D context of operating a car, to the 3D context of operating an airplane.

> Non-pilots commonly think engine thrust will cause the airplane to speed up, but usually that's not what happens. Although the airplane is being pulled forward, the trim mechanism notices what is going on and immediately converts the new energy to altitude. Therefore the throttle can be reliably used to control up/down motion. As discussed in chapter 6, this is the normal, natural aerodynamic behavior.

I reiterate that in flight, if you (and the autopilot) leave the yoke and trim alone, opening the throttle just makes the airplane climb. If you want to change airspeed without an altitude excursion, you will need to adjust the throttle *and* the yoke, as discussed in section 7.2.

A car, of course, will speed up when you open the throttle. But this has got nothing to do with the behavior of an airplane in flight.

An airplane is not the same as a car. Cars don't have trim. Cars aren't free to move in the third dimension. (Denker 1996)

What is logical in the context of a car cannot just be transferred to the new context of an airplane. Likewise, we cannot transfer the subjective rules of operation from one social context to another. However, when you focus on the central energy, you can get the general principles to solve problems in any context rather than trying to figure out each one on an individual basis, context by context. That's a huge amount of analytical territory to try and cover, which makes the approach less effective. This is the kind of counter-intuitive navigational advantage that an empirical approach can give you. It helps you reconcile your perceptions to the actual dynamics of learning so that you do not inadvertently disrupt the process. Basic Social Math helps me map out and understand how *real* learning dynamics work.

There is an age-old conundrum in the pilot community: Some people suggest that the yoke controls altitude while the throttle controls speed (just like in a car). Other people suggest just the reverse, namely, that the yoke controls airspeed while the throttle controls altitude.

So, which is correct?

Answer: neither one is correct. Both suggestions are based on wishful thinking. You might *wish* for an airplane where one control changes altitude and nothing else, while another control changes speed and nothing else, but that is not how real airplanes work. (Denker 1996)

Now, when we think about the practical problems and social mechanics of helping another adult learn how to function in a new complex system, how do we apply these concepts in an actual operation?

Rather than worrying about all the cultural variations, all I have to focus on are a limited set of variables. So in the complex system of the classroom, I'm only tracking 4 key variables in the learning cycle and 4 binary connections between them, shown here. This gives me a logical framework to use to decode the complexity and guide my decisions in uncertain and changing

conditions. It also creates operational alignment in how we interact because it's based on the empirical context, not on cultural value-sets.

Even though each class varies, the key variables never change. I do not track progress based on cultural maps (checklists, stereotypes), but rather based on the results achieved as students move through the stages of learning (which I'll explain shortly). I also don't navigate by any of my internal maps from previous contexts, because they are likely to create a mismatch problem resulting in conflict. In this way I completely bypass all the cultural conflicts and focus only on the students' development. All the different perspectives and beliefs of the individuals in the group can thus be given due respect throughout the course of operation.

The end results are what matter most. But it's not a case of "the ends justify the means" either. There are operational constraints, which I won't go into here, but that are similar to the parameters set by insurance underwriting to avoid any probable liability in the social interaction. In other words, the ends do not simply justify the means, but they do speak the loudest and carry the most weight in the decision picture for the classroom operation.

To illustrate how this is applied, let's consider an example from my classes with students who had English skills in Reading and Writing at about a 2nd or 3rd Grade level in US Elementary Schools. During my first year working with these students, I told them to choose a book to read independently at home. I would then ask them each morning to tell me about any new words they found so we could discuss the meaning and share the new vocabulary with the rest of the class. What ended up happening was that 4 or 5 students out of 15 to 20 in the class would actually do the work. The rest would sit idly by and maybe sometimes write down a new word or two. This structure wasn't working very well.

In order to figure out how I could reengineer the class in a way that would better propel students through the learning cycle, I began by evaluating the key variables and the connections between them.

The connections are a binary variable, in that the answer to the question each poses (illustrated here) is either "yes" or "no," except in the variable of "Experience," where the answer is either "positive" or "negative."

So the first question I considered was whether or not my students knew why they wanted to learn to read and write in English. If they don't know why they want to learn, then that would explain the lack of motivation to do the homework that was assigned.

Next, I considered whether or not they were taking personal responsibility for their

decisions to read or not to read. If they weren't taking responsibility for their decisions, then that would explain why they would be willing to pay a large sum of money and not take away any benefits from the class.

Then, I considered whether or not their internal maps of the classroom landscape matched the structures that we were actually using to operate. If not, then that would explain why they were coming to class, but not actually doing anything to improve their reading and writing skills.

Finally, I considered whether their experiences that resulted from the interactions in my class were positive or negative. I wanted to give them positive experiences so that they would be motivated to do the work required to actually learn. But I also knew that some would still choose not to do the work, so I could not shield them from a negative experience such as repeating the course.

So what did I actually do to restructure my approach?

Well, the answer to my first question was no, most of them did not know why they wanted to learn how to read and write in English. These students were coming from a social context where emphasis is on oral communication, not reading and writing. They come from a wonderful tradition of storytelling, but it's done orally. They didn't have the same experiences as I did with reading stories. So, I had to come up with an approach that would give them positive experiences with reading in general, because they did not have access to this kind of experience outside of the class.

Assigning reading as homework was actually creating a negative experience because it was a difficult exercise for them to actually do on their own. Therefore, I decided to restructure the reading exercises altogether. In my second year, Reading and Writing Classes began with "Story Time." Instead of making them struggle independently, we would read the stories together as a class. Furthermore, I would read the first story to them in its entirety so that they could experience the story itself rather then get mired down in the task of reading in a new language. Suddenly, all of the new words that I knew they should be finding from their homework, we found and discussed together. Many of the students also commented that this was the first book they actually read a book, and they liked it!

Miracle of miracles, I found something that worked. Does this mean that I can simply repeat the same actions with the next group of students to achieve the best result? That would be the linear model approach. When things are changing rapidly, that doesn't work very well. What Basic Social Math gives me are the tools to calculate a more accurate decision picture for every situation. It gives me a more technically precise way to repeat the **process** with consistency, not merely repeat the same set of actions. It helps me make sure that my own performance is coherent so that I can successfully navigate the changing local conditions.

Here again the empirical cycle provides me with the basis for self evaluation in the social exchange. In addition to the questions I asked myself about the experience of students, I also consider the questions shown here about the 4 key variables in the cycle. As I complete the same cycle with the students that produced either a positive or negative experience, I ask myself what I want. If the experience was negative and I wanted something positive, then I know I need to change something.

To figure out what that might be, I then consider what I can do to actually help the students. I have to also think about my responsibilities and hold others accountable for theirs.

Next, I consider how well I actually know the landscape that we are working in. In the case of language learning, do I really know what it takes to become functional in a new language? Have I gone through the process myself so that the maps stored in my memory are accurate?

Finally, I consider the results of my own actions. Am I helping the students or not?

These are simple questions that I use to decode all the complex behavior in the operation of my class. They help me break up the interactions into specific components—better detail-level analysis—so that I can calculate a decision picture for each student and class, without type-casting.

Here is where the frameworks of math help us see the flaws that we otherwise have difficulty seeing. To correct the errors in our current economic and decision theories, we first have to make the shift from a linear paradigm to this multi-variable, non-linear way of thinking. It's like going from a world that is flat to a 3 dimensional globe.

In the Spring 2009 issue of *Analytics*, Jerry Banks, a retired faculty member of the School of Industrial and Systems Engineering at Georgia Tech, and Randall Gibson, a senior vice president in the Management and Supply Chain Group at TranSystems, explained why it's important to have a clear understanding of the underlying process for problem solving in a complex system:

> It is critical for the analyst to have sufficient understanding of a process in order to correctly model the data values it will take on in the simulation. For example, if the Poisson process describes the arrivals, then the time between arrivals is exponentially distributed. On the other hand, when no data is available, understanding the underlying process allows for some initial guesses for input distributions (Banks and Gibson 2009).

When we are facing unprecedented circumstances, with no playbook to refer to, Basic Social Math gives us the framework by which we can simulate possible variations and increase the measure of predictability in new combinations of the key variables and general dynamics involved. We can see when something is going to increase the probability of conflict, learning, cooperation, etc., without having to test every detail in ways that make decisions freeze up.

This also allows us to explore and test creative new solutions, like the way we would work with models and aerodynamics to create new aircraft. This is how I apply Basic Social Math to the structures I create in the operation of my class. It's also how I was able to flip things around with the Teacher/Student role reversal that I mentioned earlier.

When you know the landscape, it's easy to keep your orientation regardless of how things vary and change from student to student and from group to group. Role reversals are easy when you focus on the empirical process rather than the traditional or cultural hierarchies. It doesn't matter how we get to the learning, because in a non-linear system there are multiple correct "answers" or paths to the target outcome.

Anyone in the group can be the leader, because we all go through the same process of development. We are all individual agents operating in the same complex system. This makes the operation more flexible, but not without limits.

Here is where Basic Social Math comes in to help map out the limits using math and empirics, not culture. In an article about mapping language in database applications from computer programming, writer Francis Richard made the following observations:

> A map is a picture, a rendering in two-dimensional space of three-dimensional topography ordered through the filter of four-dimensional experience. A map establishes spatial relations between landmarks, commits these relationships to a particular scale, and aligns the resulting picture so that a viewer (reader, orienteer) can enter it. Its use-value lies in articulating connections: 'You Are Here,' 'This Is the Place.' Such connections may be situated anywhere along the continuum of quantitative accuracy, from the pristine measurements of a United States Geological Survey plat to the sketch you scribble for a friend so she can find your house from the subway. Like naming and counting, mapping is a method for articulating the existence of things—an operation causing chosen features to rise like newborn islands from the chaotic welter of experience, fixing them in timespace and bestowing (or foisting) upon them a significance that allows these features to be found again, to be approached from new angles while still holding them in the context of previous encounters. Maps index reality in layers. (Richard 2001)

The question is this:

> What level of precision and accuracy do we want to achieve in mapping out the mechanics of various social interactions like the teacher/learner relationship?

If we care about efficiency and innovation, then we need to find ways to apply math to the process. This is the primary realm of application for Basic Social Math; to create decision pictures that look more like a digital pic rather than an artist's portrait.

Chapter 7: Analysis

One of the biggest and most troublesome unanswered questions in current economic and decision theories revolves around the issue of whose values are being used in various calculations. In a CORS Bulletin published in November 2007, Professor Barzilai elaborated on the methodological errors this creates in the existing curriculums and textbooks of Operations Research and Social Science:

> The assignment of values to objects such as outcomes and coalitions, i.e. the construction of value functions, is a fundamental concept of game theory. *Value* (or utility, or preference) is not a physical property of the objects being valued, that is, *value* is a subjective (or psychological, or personal) property. Therefore, the definition of *value* requires specifying both *what* is being valued and *whose* values are being measured. Yet *whose* values are being measured in the construction of game theory concepts such as the characteristic function of a game is not specified in the literature. (Barzilai 2007)

Barzilai lists other shortcomings that render these theories unsuitable to serve as the mathematical foundations for any discipline. This is a major problem for both practitioners and academics. It's a case where the standard textbooks and curriculums are teaching errors as though they are well established facts, something akin to teaching that the world is flat and explaining how we should operate in a flat world. You would think that in the face of such a major problem, there would be great alarm and researchers would be urgently working in large numbers to fix the errors, but they are not. The recent economic and financial crisis has clearly demonstrated that fundamental problems exist, but what corrections have we made in the curriculums or theories?

This is where our collective behavior in the complex operations of the global economy does not appear to be very different from the behavior of my students in the complex operations of my class. Why can't we make the corrections?

In game theory, the assumption is that the values people are using are all the same, but that is only from the perspective of a single cultural context. Now, in the global context, this causes conflict because it forces everyone to accept the subjective values of the dominant culture, rather than respecting the differences and usefulness of multiple perspectives. Math doesn't work with values it that way.

In math, the more angles from which you can view a problem, the better you can solve it. This is another benefit that a mathematically rigorous linguistic frame has over culture-bound perspectives. Having different values is not a problem. Ignoring differences and imposing values, however, is a problem. What we need is a way to synchronize and coordinate those values to create alignment and coherence in our operations, not conflict. This is where math and core emotions come in.

Values are a thorny issue because they cause us to face things that may be unsettling psychologically and emotionally. For example, a values realignment that puts a student in charge of the class may cause too much fear that we teachers will lose control. So rather than taking risks and facing our own fears, we often fall back on the traditional approaches we know and do exactly what the Saudi student did in his writing. We use the values and structures of a previous operational context that we are more familiar with in order to operate in the new complex system. The practical result is that we impose our own values on others and we create operational incoherence. But math can give us the tools and confidence to overcome the mental barriers that hinder our own performance in new complex systems.

When we say that teaching is subordinate to learning, this cannot be a gimmick that we use as a selling point, but one that does not carry weight in our actual operational decisions and structures. It literally means that I cannot impose my subjective values as the teacher onto the students. I must respect what they value and want as individuals or no learning can take place. I cannot manipulate them by using various "carrots and sticks" either. We have to find ways to cooperate effectively as intelligent agents in a complex system. Examining how this plays out in the classroom can give us important insights into how we can approach the same issues in the larger economic and systemic problems we now face.

Basic Social Math provides a way to build the conceptual bridge needed for a broad public to gain access to a more mathematical approach to working with social values in problem solving. However, the process of acquiring functional ability in this new way to operate represents the same challenges as learning to function in a new language. Making corrections is one of the most difficult things to do, so to be effective it is critical that we have a clear understanding of the underlying process of development.

The following is the map that I use for the operation of my class. It's a simple guide that helps us know what to do operationally on a day to day basis. It's the first thing that I show students so that we all have a clear map of the operational landscape. It's based on my own work and the work of Jenny Rardin and Tom Miller in Counseling Learning that they call the Five-stage Process and SAARRD.

The following shows how the various linguistic terms match up between our slightly different representations of the same "Stages of Learning" that students move through as they progress from total dependence on the teacher to final independence when they reach their learning targets:
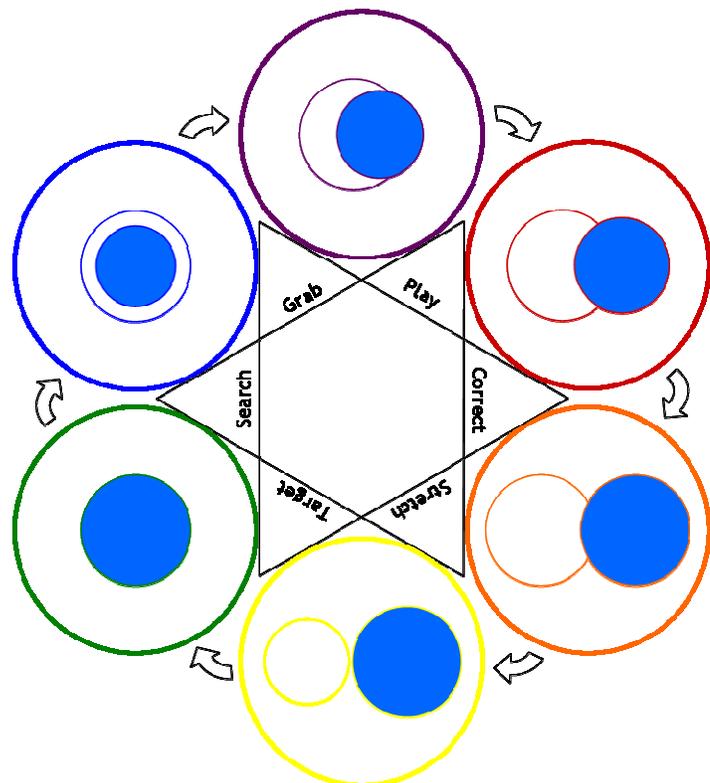
Security = Search, Attention = Grab, Assertion = Play, Reflection = Correct, Retention = Stretch, Discrimination = Target.

Here again we find that emotional undercurrents are providing the basis of alignment between the various linguistic representations of the same underlying process. "Emotions are critical to the patterns of learning that occur in the brain. We think with our feelings: we feel with our thoughts…" (ASCD, "Update," 1993) Security is something students feel and it is "the foundation on which the other elements of SARD are built." (Miller 2006)

I'm not going to go into a lengthy explanation of the Counseling Learning approach, but I do want to show the conceptual alignment that Basic Social Math can bring. This is one of the main benefits, because it can greatly simplify how we approach and solve a wide range of complex problems. To see how, we have to put ourselves in the shoes of the Saudi student and look at problems from his perspective as a learner.

Speaking of the 'coordinating process' that language teacher should engage in to incorporate a student-centered component, Barry P. Taylor recounted that, "Johnson (1979) has suggested that real communication requires that both the speaker and hearer attend to many factors quickly and at the same time. A communicative methodology, therefore, will need to provide students with opportunities to engage in extended discourse on real topics, using real language and, most importantly, in real time." (Taylor 1987) But we can see how much difficulty the Saudi student was having with simple English, so where do we begin when adult learners can say very little? To answer the question, we need to understand the exponential growth rate that occurs in functional abilities as learners develop:

- Underlying Structure
- Integrating Perspectives
- What's Logical?

- Translation & Conversion
- Synchronizing Abstract Ideas
- Parallel Relationships
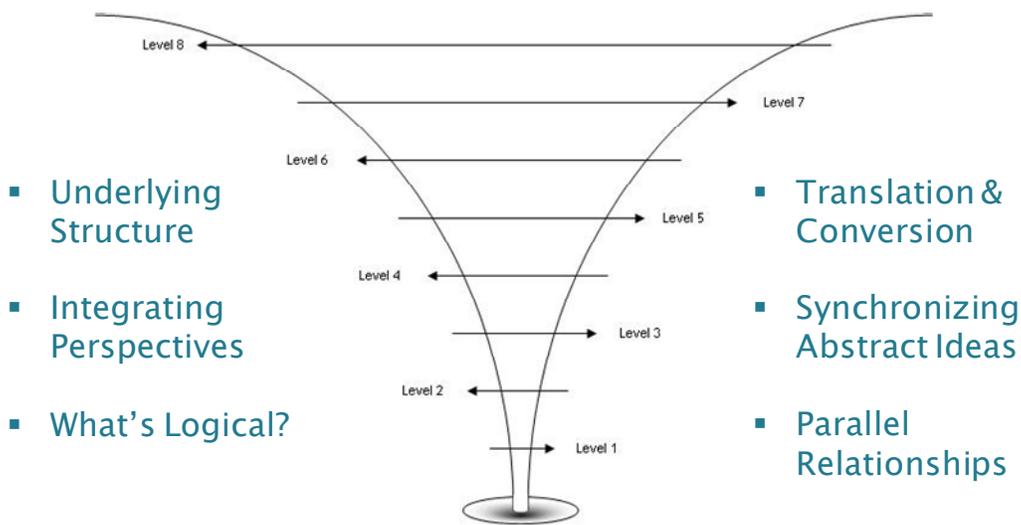
Tracking Functional Ability

At the lowest levels, I start with the simplest components of the complex system—sounds. If students can do nothing else, they can at least start producing English sounds. So we begin with games that require students to use English sounds so that they can begin making decisions and taking actions that will propel them through the learning cycle. As they make mistakes and get feedback from the

experiences, development begins to take root. Then, we move to structured exercises where minimal phrases are required. I model the exercise a few times and then ask who would like to be the teacher. From that point forward, I am only an assistant to the teacher. Whoever takes that role for an exercise must then use whatever English he has to work through the task with the other students. As students acquire more and more of the structural components of the language, their functional ability broadens as shown in the illustration here.

> During these real communications, at the practical level, the language counselor is aware of the choices learners are making—whether to speak at all, to whom to speak to, what to say, listening for the 'foreign' sounds that in the beginning seem not to make sense, and reproducing them as accurately as possible. (Miller 2006)

So when is correction appropriate?

Development is an internal neurobiological process that cannot be forced externally. This sets important environmental constraints that are not subjective. Developmental trajectories are individually unique, but the general process is universal. These stages of development determine the relationship dynamics of the social exchange. Again, it's not something that I determine based on my values as the teacher. It's something empirical that I seek to observe and gauge accurately, so that I can respond appropriately in order to help students reach their learning targets. Correction is just one out of six possible stages and the timing for when it's appropriate is determined by the student, not by the teacher. So I have to coordinate and synchronize my actions to match what the students need at any given time, which is substantially different from the traditional, teacher-centered approach.

Consider the example of Ahmed Zamil, a student who probably had the lowest skill level in a special summer course that I taught for high school age students. He couldn't speak much English, but he was funny! He usually sat idle during most of the exercises we did together in class. He then copied his friend's answers. He was often disruptive and often late to class. But oddly enough, he came regularly. So I saw no need to hassle him as long has he wasn't interfering with the other students' development.

Towards the end of the course, we did a final dictation exercise where one student would be the teacher and the other students would write down everything he read from a text. We had attempted this same exercise the week before and, even though the best speaker in the class was the teacher, the class descended into chaos and I had to intervene. So this time, when I asked who would be teacher, I was stunned when Ahmed raised his hand. I almost laughed out loud from the shock. Then I stopped myself and did the unthinkable. I handed the text to the class clown. Next, it was the other students who started laughing and objecting, which convinced me that it was the right thing to do.

Ahmed was a natural leader. Even though his English skills were low, his leadership skills were solid. He stood up in the face of all the scoffs from his fellow students and took command of the class. As the assistant class clown, I stood close by his side to give him the help I knew he would need in order for the exercise to be a success. He wanted to show his peers that he could read the English words; that he was just as capable as they were. I knew that this was also the only way for him to actually complete the

cycle that would further his learning. And though he made a lot of mistakes, wow, what a performance! The expression on his face says it all.

He surprised, captivated, and inspired us all to the benefit of everyone's learning, including my own.

So how did I do the decision calculations that enabled me to navigate in real time and achieve the best result for this situation? Well, what I didn't do was use a linear string of actions from a traditional approach as the basis for my calculations, because that would have equaled me telling the class clown no. If we just use a linear list of "do's and don'ts" to navigate, then we are going to play the role of a policeman running around correcting every error that we see. This doesn't use abstraction. But if we learn to calculate by abstracting the central "energy" of learning, then we can play the role of a true guide. Operationally, there's a big difference between the two approaches.

When we shift to a new context, we find that linear maps nolonger align properly with conditions on the ground and our effectiveness is greatly reduced. We cannot simply go into a new context with the behavior checklists from another setting and expect to hit targets the same. This is the "Chinese Kanji" approach to functioning in a complex system, where a different symbol (or behavior checklist) represents each variation. Trying to keep track of all the possible variations is limiting and cumbersome in ways that lead us to conclude that the calculations are more complex and difficult than they need to be. It doesn't use the power of abstraction to make things easier.

Using abstractions as a structural basis of the classroom operation allows for a much wider range of behavior to be accommodated. Instead of being restricted to a narrow list of actions that are on the "approved" list, even behaviors that might be construed as bad can become the drivers of learning. Different behavior types simply become the indicators of which stage learners are actually in. This gives the teacher important cues for how to structure activities that will be appropriate for learners in any given stage. For instance, before we can get to the stage of Correction, learners must have the opportunity to "Grab" and "Play" with the new and unfamiliar components of the target content.

What this means structurally, is that "Play" is an integral part of the day to day operation of the class. Allowing the students to take the teacher's role is, in fact, a form of Play. We play the game of "English Class" until students reach the point where real learning can begin. Then, their behavior changes and they begin to ask questions about correctness. This is my cue that correction is now appropriate. Prior to this, it doesn't really matter if students goof off because it's just a game after all. The abstraction helps me locate the behavior type within a predictable pattern, which then enables me to respond appropriately.


Social Functioning In Learning Contexts
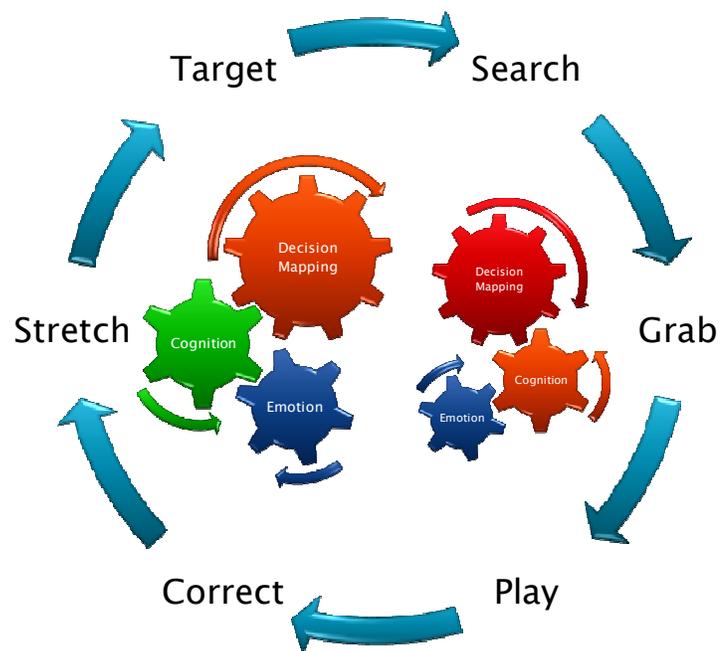
The ultimate test for this came with Abdullah and a Beginning-level Reading and Writing Class. Abdullah was 18 years old and he had been born in the United States. He went to elementary school there and then moved to Saudi when he was 11 or 12. He could speak English very well, but he never learned to read and write. On top of that, he had an ego the size of Mount Everest. So, when we played the game of English Class, Abdullah wanted to prove to everyone just how much better his English was than theirs. Since I was the only one in the room that knew when he was making mistakes, he saw me as a threat to his image. He went on the attack and tried to be outright disrespectful. Once again, I had to flip the dynamics in a way that directed his movement towards the target of learning, but I had to let go of my ideas about traditional classroom structure in order for this to work.

In the game of English Class, the teacher was the boss, so Abdullah immediately volunteered. This meant that I had to subordinate myself to the learning and that Abdullah had to then demonstrate to his peers exactly what his skills were as a teacher. This is where I knew that I had him cornered, but he didn't know it, yet.

Abdullah was in what Counseling Learning calls the stage of "Assertion," where he grabs what he wants and plays with it. Since he had spent several years in the US as a child and young man, he wanted to challenge my authority, and understandably so. He wanted to emphasize his superiority, but this is constructive energy, so I wanted to redirect that against the empirical context of the language itself, not against me. If it's against me, then it becomes a contest of wills between the teacher and the student. This has nothing to do with learning the language and it can completely arrest development. This was the last thing that I want because he will get distracted by the conflict and he won't experience anything new that will drive changes in his neuro-circuitry.

So, in order to redirect this energy successfully, I must know the territory that we are in better than him. I must be confident about where we are and let him find out, and thereby show everyone, exactly where he and I are not equal in this regard.

In his mind, he knows more than me and he wants to prove it. I know he's just being a smartass like I used to be, so I'm not afraid to let him try. However, in order for it to work I have to be willing to let him "Play." So, as long as it doesn't totally disrupt the learning of the class, then he's in charge.

This is something that is difficult to do if I have created a linear structure for the course where we plod through the material and never look back once we've covered something. Instead, the class is cyclical and repetitive, so we have the freedom to make mistakes and play.

Since I knew the territory of learning languages and I knew that Abdullah wanted to show off, I also knew that I had nothing to lose by turning the class over to him. He didn't want to lose face with his peers. But I knew that the task was one that would be challenging even for him. So, when he ordered me to go out to the cafeteria and relax, I didn't agree. I knew he would reach the point where he needed my help. However, I did agree to stand outside the closed door of the classroom, where I could at least see the students working.

Other students passing by in the hallway gave me a stunned look and asked what was going on. I replied that it was a test. They were even more shocked and they asked why I was outside of the class then.

"The students will cheat," they warned.

I told them that cheating was impossible on this test. And sure enough, Abdullah soon got as far as he could go and he hit a wall. He found the place where he didn't know something and he had to come ask for help. This was precisely the place that I wanted him to find so that I could then do my job of facilitating development. If he didn't find this place, then I couldn't do my job. Only he can find it and that is why teaching is subordinate to learning.

Hence, this is a principle that sets key parameters and constrains the decisions that we all make. It's one of the key relationships that I must understand in order to navigate, and help others navigate, without creating cognitive inaccuracies in the learner's mind. They intuitively know that they are in control of the process. If I try to subordinate them to what I want, they will sense that something subjective is going on.

So it's very important for me to demonstrate that I am at their service. I must also know the territory and be able to guide them from the place where they feel like they don't know to where they feel that they do. If they get lost, then I lose credibility. If I force them, then I also lose, because they don't develop the internal criteria they need to improve their functional ability in my absence.

I gain credibility by making accurate decisions in how we operate collectively and this is important for all the class to see. Not to emphasize the inequality between us, but so that both they and Abdullah will be willing to take risks based on the directions I guide them in our future pursuit of the course learning objectives. This was the lesson that they wanted to learn that day and I had to be willing to follow that energy and demonstrate my own competence in this regard.

If I forced my agenda, then I would have been the obstacle to Abdullah's learning and he would have formed a different opinion about my competence as a teacher and leader. He would use me as the excuse for his failure to learn and I don't want that cognitive inaccuracy to take root in his mind. That is why my teaching has to always be subordinate to the student's learning. That's also why, in the way I structure our relationship, I never want to come between the student and the empirical context of the target language or the experiential learning cycle.

So, what does this teach us about credibility and authority? Do the dynamics change when we move up in scale and complexity for collective decision making?

Operationally, we need a clear assignment of roles and responsibilities, not by way of force, but by way of empirical constraints set by developmental requirements and neurobiology, so that we don't experience cognitive inaccuracies that hamper development. So, yes, we want the students to be responsible for their actions, but we also want them to develop the internal criteria for how and why they are responsible, so that they will be able to be responsible independently and of their own accord, not because they are being forced.

That is something that requires an understanding of multiple variables, not just a checklist of actions. The empirical context itself is what helps us accurately determine who is responsible for what. This information then enables us to accurately assign roles in the task of learning. In the *Annals of the New York Academy of Sciences*, Charles E. Bailey elaborated on the impact this has in business operations:

> Cognitive thought processes depend on specific brain structures functioning as effectively as possible under conditions of cognitive accuracy. However, typical cognitive processes in hierarchical business structures promote the adoption and application of subjective organizational beliefs and, thus, cognitive inaccuracies. Applying informed frontal lobe executive functioning to cognition, emotion, and organizational behavior helps minimize the negative effects of indiscriminate application of personal and cultural belief systems to business. Doing so enhances cognitive accuracy and improves communication and cooperation. Organizations operating with cognitive accuracy will tend to respond more nimbly to market pressures and achieve an overall higher level of performance and employee satisfaction. (Bailey 2007)

Social hierarchies, by nature, promote the application of subjective beliefs. Why? When conditions are changing rapidly, the "authority" figure most likely is using old internal maps for a new context.

So rather than play the linear, checklist game of 'cat and mouse'—where I assign a list of books for students to read at home, then chase them around to see if they did it—I spend the first week of the class helping students understand the stages of learning. I try to clarify what their role is, and what my role is not, as we cycle through the learning process. I only enforce uniform standards as behavior relates to this non-linear cycle. I help everyone understand the context limits. I provide a successful model of language learning and I leave all the variations for their individual success or failure in their own hands. It's a simple and efficient approach that takes into account all the variables that are in play.

As we begin to bring the underlying mechanics into clear view, we can better see what to experiment with. When we understand that the key variables in the cycle are what we need to pay attention to, then we can begin testing hypotheses in the classroom to see if they lead to the destinations we desire.

> I reiterate that in flight, if you (and the autopilot) leave the yoke and trim alone, opening the throttle just makes the airplane climb. If you want to change airspeed without an altitude excursion, you will need to adjust the **throttle** *and* the **yoke**, as discussed in section 7.2. (Denker 1996) [emphasis added]

We can't just ignore what students **want** and force them to do work. We have to spend time with this variable, too. We cannot just focus on **actions**, or a linear list of "dos and don'ts" we have mapped out.

If students want success, they have to take it. My responsibility is to facilitate, not force feed. The ones that want it, take it, and perform very well. The ones that don't are welcome to come play with us until they figure out what they want. When I have an accurate picture of the underlying stages and process of learning, I gain an internal sense of what's correct and incorrect, or in other words, coherence. This guides my decision making in uncertain conditions because it allows me to calculate probable outcomes based on local conditions, without getting lost in the variation. It provides the basis for judgment; the internal framework for decision logic that is universal, not culture-bound.

Here again, the structure of Agent-based Modeling helps me to breakdown the components of the complex system into comprehensible patterns. As one agent in the system, my navigational decisions are based on the natural limits set by the stages of learning and localized information. This universal structure under the complex system of the class establishes the real world constraints that apply to all of the agents in the system. These parameters of operation are determined by our neurobiology, not by subjective cultural frames or value sets.

By using these empirical components to navigate, I can more accurately determine which course of action will produce the best results even with sudden changes. I reconcile all our interactions to the empirical context and target outcome of learning, to get a specific decision equation for each student or class. Here's a breakdown of the complex system:
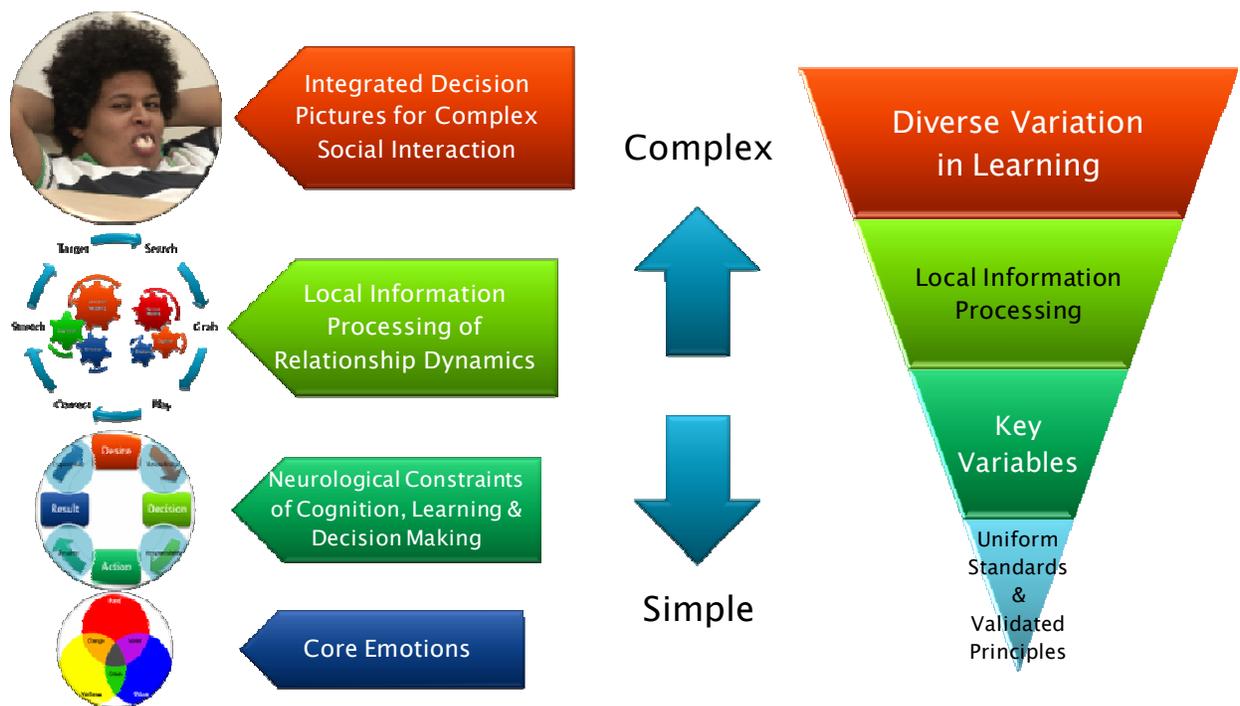
So the reason for this analysis is to use what we know about how complex systems function, so we can work in reverse to identify and validate the key structural relationships that can be abstracted for broad application in various contexts of social problem-solving. We don't want to do this by using existing cultural frames, but rather by working within the empirical framework of neuroscience so that we don't

bias the picture like that of the Chinese artist. We want the general principles and relationship dynamics that can be validated and codified as part of the functional policies for any social operation.

We want this because the dynamics of each group of students change just like dynamics change in the global economy. You can't just repeat a linear set of actions from one context and expect them to work in another. We need to be able to use general principles and unleash the power of abstraction in order to achieve broad application of successful methods in hitting target outcomes (flight, learning, etc.).

In essence, Basic Social Math is about reconciling social values at the subsurface level, not trying to reconcile the behavioral manifestations at the surface. It's about creating uniform and mathematically rigorous standards, based on the empirical framework of neurobiology, that create alignment at the structural level of our complex social systems, not trying to fix problems at the surface, ergo the writing sample from our Saudi student:
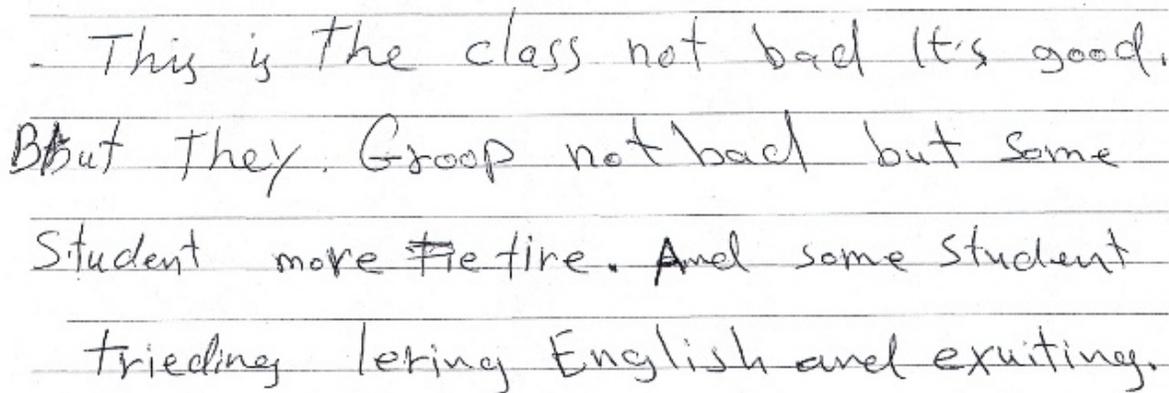
Which is more efficient: memorizing the correct order and spelling for each word, or learning the correct underlying rules and structure?

So where should we focus our efforts—Complex Math and Statistics or Simple Math and Linguistics?

Where will we get the most bang for our buck to improve our functional abilities in the global system?

Only by examining the empirical components of decision making and social interactions through the more rigorous linguistic lens of math can we begin to see further into the complexity of the social world than is possible using natural language alone. Basic Social Math seeks to do just that, but it requires us to work in a new direction; one that lies at the fundamental end of the mathematical spectrum, not the complex end. Simplicity should not, however, be mistaken for easy. Whereas Calculus was developed about 300 years ago, the Arithmetic that gives Calculus its wings took several thousand years to develop. These are the same fundamental tools that we now need to integrate into our social calculations in order to unleash their problem-solving power in the social sciences.

Chapter 8: Synthesis

Now as we step back from what's happening at places like Yamamah University and take another look at education in the United States, we find that the changes and problems I've been trying to illustrate are a lot closer to home than we might have suspected. In a recent online debate published in *The New York Times*, the Editors posed questions about the structure and approach of our own teacher education and certification system. Many of the same problems of linear and hierarchical thinking quickly emerged. The comments of Patrick Welsh, an English teacher at T.C. Williams High School in Alexandria, Virginia, provide a good snapshot of what's happening systemically:

> The credentialing game in public education may have once been a well-meaning effort to create some measurable criteria to maintain standards, but it has turned into an absurd process that forces both teachers and administrators to waste time jumping through hoops that have little or no relation to their job performance. (Welsh 2009)

I hope at this point that I have adequately illustrated why the current, linear approach doesn't work. If we want to solve problems in innovative new ways, we need to dig deeper to see what's happening under the surface at the structural level. We also have to remember that teachers are intelligent agents that now need to function in much more flexible ways given the changing dynamics of the global age. Consider the comments posted in the same forum by a reader named Jeannette from Santa Barbara:

> I am a 6th grade teacher in a southern California public school. I have a 4 year BA in literature and a 5th year teaching credential, both from UC Berkeley. I also have a CLAD certificate for working with second language learners. I am qualified by CA standards. The issue for me these days, as I begin my 14th year, is classroom behavior. I used to have one student a year who lacked civility or any interest in attending to anything. Last year I had 6 such students, who each had a family story, of prison or abuse or alcohol or drugs or whatever, but the bottom line, my class was so much more difficult to teach, because several parents were not doing their jobs at home. Add to that issue, the 8 students from another country who did not have English as a first language, who have lived in this country for more than 5 years and still cannot read or write on grade level and who are living in several different homes with no particular interest in their studies or the value of their education. I have never worked so hard to teach and review and tutor, etc. and yet many of us teachers, good teachers, are having a struggle fighting this tide of behavior issues and indifference. Believe me, we attend the workshops, earnestly work in our classes, talk with the parents, struggle with the kids, and still, it is not always enough. (2009)

How do we make such broad systemic upgrades? Individual agents need a way to calculate optimal solutions based on local conditions. This cannot be done using subjective, cultural values. It must be

founded on fully generalizeable social and biological processes that do not change from one context to the next. This is where the underlying processes of learning and decision making need to be validate for general application across disciplines and cultures. Fields like Operations Research have a tremendous contribution to make in this regard, but how? How do we resolve the structural mismatch and lack of clarity in the bigger picture?

To answer the question we have to take a look at the functional relationship between Calculus and Arithmetic and the purpose each serves in a linguistic framework of making meaning. This will give us clues as to what we need to clarify our views of the complex social interactions in the bigger picture of our global systems.

We have to examine math as a problem-solving framework and consider how we solve the complex problem of *Learning*. Here we see that Calculus is built on a mountain of incredibly powerful problem-solving tools, with Arithmetic being the most broadly applicable. These are the mathematical tools that I am interested in unleashing onto
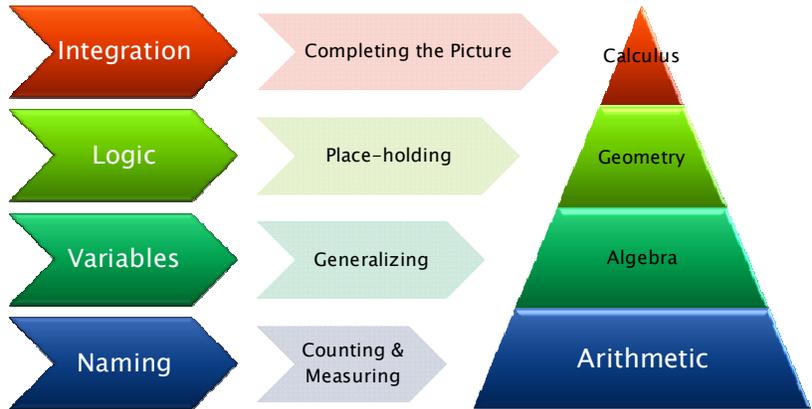
the monumental social problems cited above. Remember that we need to think about how we can capture and convey the "mathematical knowledge for teaching." To do this we need to acknowledge that our neurobiology and the learning cycle are universal, not culture-dependent, processes. These empirical components determine the real limits and simple rules of our complex social systems, and for all practical purposes, they remain constant. That means they are indeed generalizable.

Think about how the Calculus and Arithmetic work together in communication. When someone speaks to us, grammar provides the simple rules, the sounds and physiology provide the context limits, and based on these limited, constant patterns, we are able to make sense of all the various words and phrases people say. When someone speaks with an accent, they can be difficult to understand because they are unconsciously shifting the context limits. Our brain, then, cannot properly align the sounds with our internal context of meaning, causing the calculus not to work because of this arithmetic level mismatch.

In the global context, we see the same thing because the old constraints of culture are being swept away. We find ourselves operating within a new and unfamiliar set of context limits, which is causing things to be difficult to understand. But this is where we are not left without stars to steer by amid the darkness of complexity.

Let's return again to comments made by David Brooks about emotions and their place in our complex systems of social interaction:

The rise and now dominance of this emotional approach to morality is an epochal change. It challenges all sorts of traditions. It challenges the bookish way philosophy is conceived by most people. It challenges the Talmudic tradition, with its hyper-rational scrutiny of texts. It challenges the new atheists, who see themselves involved in a war of reason against faith and who have an unwarranted faith in the power of pure reason and in the purity of their own reasoning.

Finally, it should also challenge the very scientists who study morality. They're good at explaining how people make judgments about harm and fairness, but they still struggle to explain the feelings of awe, transcendence, patriotism, joy and self-sacrifice, which are not ancillary to most people's moral experiences, but central. The evolutionary approach also leads many scientists to neglect the concept of individual responsibility and makes it hard for them to appreciate that most people struggle toward goodness, not as a means, but as an end in itself. (Brooks 2009)

What tools do we need in order to create accurate alignment between complex systems like language and culture? Look at how this is done in the less complex example of aligning the Hijri Lunar Calendar with the Gregorian Solar Calendar. The common points of reference established by the sun and moon within the back drop of the planets and stars provide the empirical context of observation, while the "Arabic" Numerals of arithmetic provide the markers and rigors needed to keep track of the variations in days, weeks, and months. Without these humble tools, it's easy to get lost in the complexity and sheer volume of the variations. With complex social systems, we can do the same thing by peering down the microscope of neuroscience to find the empirical markers we need to establish universal points of reference that extend our vision in the same ways. For example, does a different moon fly over Mecca than over
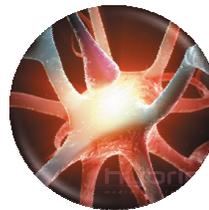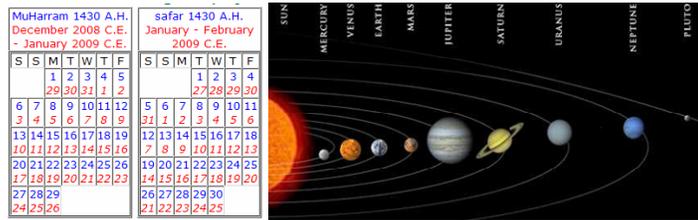
ябълка   تفاحة   apple

Washington DC? The answer is no. Therefore, we are simply going to expand his same frame of reference into the micro-universe of human neural networks in order to establish key points of alignment the same way that explorers past did with the stars in the heavens in order to clarify our collective views about the nature of the world in which we live and operate.

Basic Social Math uses the empirical context—the apple—of neurobiology, as seen through the microscope of neuroscience, to get everyone on the same page and we'll use universal processes like the experiential learning cycle to synchronize diverse operational movements (like using the freezing point of water to synchronize our temperature scales of measure). The empirical context of biology and the central process of experiential learning become the notes on the page (the micro-constellations) that everyone can refer to in the collective movement of the operation.

This does not mean that everyone is forced into the same operational box. Each person plays a different part and that part changes over time. Movements are coordinated based on the context limits and simple rules established by the stages and cycles of learning, not simply by the individual's internal, culture-bound maps that may not match the changing context.

To see how this is possible, consider what Benedict Carey wrote about how fundamental emotions serve as a platform for dealing with difficult social situations.

> For most of its existence, the field of psychology ignored pride as a fundamental social emotion. It was thought to be too marginal, too individually variable, compared with basic visceral expressions of fear, disgust, sadness or joy. Moreover, it can mean different things in different cultures.
>
> But recent research by Jessica L. Tracy of the University of British Columbia and Richard W. Robins of the University of California, Davis, has shown that the expressions associated with pride in Western society — most commonly a slight smile and head tilt, with hands on the hips or raised high — are nearly identical across cultures. Children first experience pride about age 2 ½, studies suggest, and recognize it by age 4.
>
> It's not a simple matter of imitation, either. In a 2008 study, Dr. Tracy and David Matsumoto, a psychologist at San Francisco State, analyzed spontaneous responses to winning or losing a judo match during the 2004 Olympic and Paralympic games. They found that expressions of pride after a victory were similar for athletes from 37 nations, including for 53 blind competitors, many of them blind from birth. (Carey 2009)

For navigational purposes, this is precisely what we need to keep our bearings and produce better maps of the real world landscapes that we face in various types of social interactions. When we look to the not-too-distant past and consider math's role in the technological developments of physical navigation, we find important clues to how math can be applied in social navigation. Here are some pictures of tools that the explorers of the past used to navigate and cross vast oceans of unknown territory:

(Found at http://www.waterencyclopedia.com/Mi-Oc/Navigation-at-Sea-History-of.html)

So, what kind of math takes us from these rudimentary navigational tools to GPS? If we want to achieve this kind of technological advancement in social navigation, then we have to start with basic math.

We need to be able to extend our vision so that we can see things beyond our normal range of sight in the global economy. We can no longer rely on judgments based on our local context of operation where subjective values appear perfectly coherent and functional. We need to develop the linguistic tools capable of producing scientific pictures of social interactions instead of culture-based pictures, like that of the Chinese artist.

The tools of math at the complex end of the spectrum do not help us resolve this kind of problem. We can't solve fundamental problems using complex math. We can only do it with basic math. That's the area where our linguistic frame in social science is deficient. It's an area that currently depends on cultural frames for making meaning and approaching solutions to problems. These culture-dependent frames taint all the pictures we paint of the various social problems we face today. The only way we can correct this problem is through the application of fundamental rigors of math to the linguistic frame we use for such analysis.

In the beginning stages of language learning, I teach sounds and letter combinations so that the brain can distinguish the phonemes and memes that allow it to recognize the patterns of meaning and decode the complexity of the language. Here's a reverse example of what students go through. If you speak English and not Arabic, then your brain can easily do the "calculus" in the first line because the "arithmetic" of the complex system is clearly in place.

1:   Risae yuor hnad if you can raed tihs.

2:   .

If the "arithmetic" is not in place, like in the second line, then your functional ability will remain low because your brain cannot do the calculus that delivers the message.

At first, when we encounter a new complex system, it seems overwhelmingly complicated and unmanageable. However, once we get a clear picture in our neural networks of the underlying patterns and interacting variables, then our fear and confusion are replaced by confidence and the ability to function smoothly. As a linguistic frame, math helps us break up and manage these patterns in simplified and technically robust ways. We do not currently have the level of linguistic sophistication required to reach clear and accurate conclusions about social interactions like we can in physics. This is why we conclude that there is far more variation than there actually is. That the variety is "baffling" and "we can't even fathom," as David Brooks expressed. Hence, a linguistic upgrade is required before we can reach more accurate conlcusions about this territory.

Basic Social Math seeks to correct the errors and extend the industrial strength tools and methods of Operations Research down to the consumer level. In the complex system of Mathematics, Arithmetic embodies a relatively simple and limited set of key rules and principles that broadly apply throughout the system. This is the structural level of the analytical framework of math that needs to be better coordinated to social contexts of analysis. The resulting linguistic framework would be an upgrade to the cognitive strategies we can use to create more accurate operational decision maps in complex systems.

We now have an opportunity to extend the powerful tools of Operations Research down to the elementary level for generalized application. We already know the benefits to be gained at the sophisticated level for specialized application. Now we need to open the pathway that bridges this gap and makes these tools more accessible to students, teachers, administrators and the general public. We need to look for ways that we can build down the curriculum and assert the centrality of what is essentially *Elementary O.R.,* or what I call, *Basic Social Math*, within the broader social sciences. Everyone needs these tools in order to overcome their own deeply rooted practices that are generating mismatched decision maps in the new global context. A linguistic upgrade is required to improve our capacity to process local information as individual agents and make decisions in the complex systems of the global age.

In an article published in the months just prior to the 2008 presidential election in the US, John Florez captured the essence of our challenge as intelligent agents in a democratic system:

> We complain about the failure of leadership: Leaders that abuse power are unethical, short-sighted, lack integrity, manage by crisis, and cater to special interests.

> But, what about the failure of votership? We now act as spectators, something our founders never envisioned. We've become more passive, cynical, disengaged and lazy, and we rely on labels, sound bites, and do the human thing—see the world from our own set of experiences and create our own perception of reality.

> How often do we see things we want to see, and hear the things we want to hear, take the time to understand the opposite side, or get in a healthy argument with someone and admit that the other person is right? Have we stopped growing and become comfortable with party allegiances and ideologies? John W. Gardner warned, '…there is the inclination for followers in some

circumstances to collaborate in their own deception.' Times have changed and with it so must our thinking of how we view the world. If not for ourselves, then for the next generation. (Florez 2008)

Basic Social Math seeks to provide the tools that we can use to re-frame complex interactions and balance things from the beginning based on true mathematical principles. Rather than trying to sort out all the differences between subjective cultural frames, Basic Social Math simply reconciles all calculations to a single set of empirical factors that are not culture-dependent. That way the conclusions we reach can be independently verified and validated. Such a framework allows everyone to integrate diverse points of view in ways that create a more accurate picture for all to see, rather than creating conflicting views of the same picture.

To get an idea of what this means, consider the following three views of the world. For the sake of illustration, consider that the first one was mapped out using American values and methods for navigation. The second was mapped out using Arabic values and methods for navigation. And for the third one, we need to think about what mathematical tools were used to create this kind of picture.

Venetian Map (1459)   Voyage of Francis Drake (1595)   Apollo 17 Photograph (1972)

Here is where a new linguistic frame must be used to create pictures of social dynamics based on empirical components rather than culture. The rigors of fundamental math are needed to map out complex social interactions in a new, more objective way—think digital pic vs. artist's portrait.

We need a perspective of analysis that is grounded in neuroscience and mathematical rigor rather than cultural linguistic frames. Such a paradigm shift can help us ask and answer questions like the following:

What is the state of our collective maps of the nature of social interaction and operations of economics in the global systems?

What does the big picture really look like for social dynamics and social science?

How do we go from social maps that look like the Venetian one, to maps more like the Apollo pic?

If we want people to have a clearer view of the big picture in which we now must operate, our social science curriculum should be realigned and structured something more like the illustration shown below. Basic Social Math can provide people in all social science disciplines with the technical basis for integrating their unique prespectives into an accurate view of the bigger picture in our collective decision maps. It would also guide our research to establish key variables, validate the core dynamics of complex interactions like learning, and clarify the universal constraints of decision making for the purposes of engineering in educational and social systems.
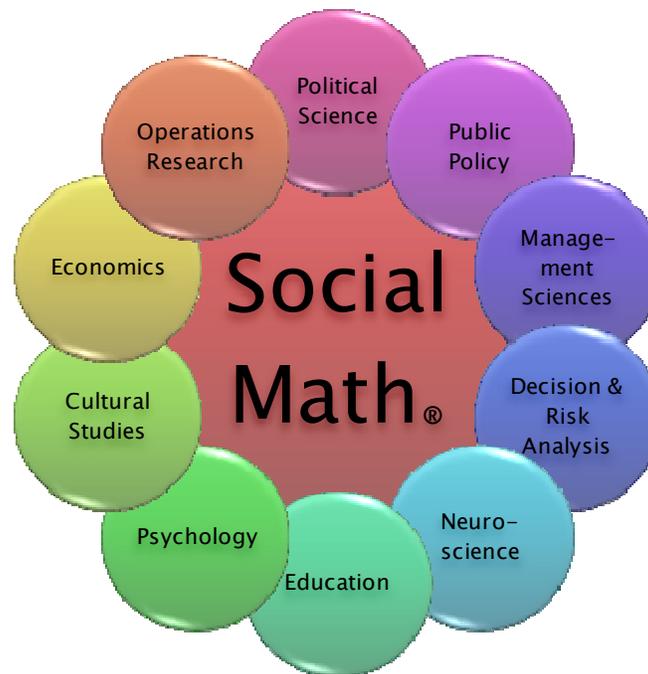
In order to better engineer our social environments, we must first seek a clear view of the general and universal dynamics of the simple, empirical processes that underlie complex social interactions. This would take us through similar steps that helped us identify the key factors in aerodynamics that produce flight. Having a clear view of the general dynamics allows us to develop more effective technical applications, like jets, helicopters, and gliders. To clarify our view of social dynamics, we must first validate similar basic concepts at the crossroads of multiple disciplines as shown above. Basic Social Math is a means to accomplishing that end.

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