A Cautionary Tale for Future Scientists and Business Leaders.

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Modern technology and, thus, our civilization rests in part on the twin pillars of Science and Business. So, a career in either of these two fields of endeavor is attractive for many bright ambitious young people. Riches and successes beckon.

History is replete with many fabuluous success stories in both science and business. Young people are told that if they work hard and have high aspirations, they will find fabulous success and rewards in these fields. But, what really awaits them?

The purpose of this Musing is not to discourage the pursuit of a career in either of these two fields, but rather to make a young person aware of the true situation that awaits them. If one approaches these careers with a realistic understanding of the situation, then one has a greater opportunity to adopt a “correct” attitude and to enjoy his/her experience.

There are some things that we elders should be telling our young people that will be discussed in this Musing.

In my experience for every fabulous success story there are many untold “failure” stories. Of course, these can be depressing and certainly aren’t good P.R. for the encouragement of young people to embark on such a career. So we can be led to unrealistic expectations.

In other pop culture endeavors, such as music and athletics, it is obvious that for every success story there are many “failure” stories. How many people do you know who are very talented and ambitious in music or athletics yet never achieve any real success, even to the point of earning a living, pursuing their passion? Of course, we read and hear a lot about the few who do. They are honored and often showered with riches. I don’t know the statistics, but I would guess that for every musician who is successful enough to actually earn a “good living” there are hundreds who fail. Some don’t try very hard, but some try all their lives and simply can’t make it. Same situation for athletics.

But, what about science or business? My guess is that the statistics are similar. Why is this so? If one studies long and works hard, why wouldn’t one “succeed”?

There probably are many reasons. But, there is one reason that is little known which I believe every young person should be aware of. This awareness may lead to a more realistic approach to their career and lead to a happy fulfilled life, even if they don’t “hit a home run” from their efforts.

So, what is this “unknown secret”?

_We live in a non-linear world which is, thus, highly unpredictable. It is very difficult to make correct decisions and choose successful paths in the world we live in. A great deal of “luck” is involved. And, many of us will fail in achieving our objectives and aspirations for reasons beyond our control. And, it’s unpredictable._
So what does this mean?  Non-linear world?  Unpredictable, and thus fraught with “danger”?  “Luck” required to succeed?

Both science and business deal with complex systems.  In order to understand them to make “good decisions” we must be able to predict the outcome of the decisions we make and the actions we take.  One wrong action or bad decision can lead to a dead end and failure to reach our objective.

We all learn to set goals and objectives and missions.  We all have visions of our future.  But, then the “rubber hits the road”.  As we engage in science or business we must make decisions and take certain actions based on these decisions.  In order to do this we must understand the situation we are dealing with and be able to predict the outcomes of our actions.

So what do we do?  How do we make decisions?

We set up models or metaphors of whatever “reality” we are dealing with.  We then use these models or metaphors to guide us in the making of our decisions, which in turn determines our actions and activities.

Sounds good.  Indeed, this is what has facilitated the human race in becoming the dominant species on Earth, and has led to our modern civilizations, particularly those based on science and technology.  This musing will not pass judgment on whether this has been good or bad for the human race.  That can be the topic for another musing.

So what’s the problem?

The most effective “language” for creating these models and metaphors has been, and is, mathematics.  Indeed, some of the Eastern civilizations recognize the limitations of any language to represent “reality” and make little effort to do so.  Those civilizations have not pursued the path of science and technology to reach their “objectives”.  But, this musing is written for the Western audience.

Now, here is the dirty little secret that underlies our situation.

There are two types of math models, Linear and Non-linear.  Think of Linear as being a straight line and Non-linear as being a curved line.  There are, of course, more sophisticated definitions for the mathematically enlightened, but these definitions will suffice to help us understand our dilemma.

When we set up a math model for whatever situation we are dealing with, we will end up with either a linear or a non-linear model.

So what?
Well, mathematicians can mostly solve only the linear models. Non-linear models must usually be dealt with simulations on computers. Indeed, until the last few decades mathematicians mostly ignored non-linear models.

So what do you suppose we do? We tend to stick to linear models for our metaphors of our reality. These are the models we can understand. We make our decisions based on the outcomes predicted by these linear models. Our intuition is usually “linear”.

This creates the problem. Most linear models are very poor metaphors for our reality. We sometimes get very bad, erroneous predictions from these linear models. We subsequently make bad decisions and take actions that lead to results we did not anticipate, and did not want. We don’t achieve our plan or mission. We “fail”.

The facts of life are: many times Non-linear models are much better, more accurate, metaphors for our reality than any linear model could ever hope to be. If we want to make good predictions, we must use a non-linear model in many situations in both science and business.

But, then we can’t “solve” our non-linear model and make any predictions at all. Wow. What a situation to be in. We’re kind of dammed if we do and dammed if we don’t.

Use a linear model we can solve to make our predictions and decide our actions, and we will sometimes be wrong and get results we didn’t want, occasionally “disastrous” results.

Use a non-linear model and we can’t make any predictions at all to guide our actions, because we can’t solve the model. Sometimes we can use a computer simulator, but even this has serious limitations.

So what is one to do?

Let me answer that a little later in this musing. First let me give you a concrete example that demonstrates this situation. This example was actually inspired by a real world example that led to the failure and bankruptcy of a great company. Those of you who have read some of my business musings will recognize the example. But, it is typical of many business situations. And, it is really a very simple example of this dilemma.

I am going to show you the graphs of two sets of data. There are seven data points in each of the two sets. Furthermore, I tell you there is an underlying “reality” that can be modeled precisely with a math model and that the future of the two processes represented by these two data sets is wholly predictable by the math model, if, of course, you can understand and “solve” it.

Your problem now is to predict the future of these two processes by predicting the future of these two math models.
Here are the two data sets, each with seven data points representing the historical performance of their underlying process, and their line graphs.

Your challenge is to predict the future of these two processes for the next seven data points into the future. Where will these processes end up seven more time units into the future? Stop, and think about it a little. Project the curves of this model seven time units.

You notice these two graphs are non-linear, that is, not straight lines.

What are your predictions for Process 1, the top graph, and Process 2, the bottom graph?

Come up with your “best guesses” just from looking at these graphs. Try to predict which process will be larger seven data points in the future. Write your answer down.

First, you might just try to extend the two curves and see what you get.

Another approach is to come up with a math model that you can extrapolate. A common approach is to approximate a non-linear model with a linear model. So, here is a set of graphs that attempt to “linearize” the two graphs. I will tell you that this linear model is not a very good approximation of the non-linear model, but it might be the best one we could come up with. This is often the situation we face in the real world.

I simply drew two straight lines that connected the end points of each of the two data sets. One could use two tangent lines in the center of the two graphs with similar results.

In hindsight, I can tell you that either approach to substituting a linear model for the non-linear one will yield poor predictive results, as you will soon see. But, you think about it and try to predict the outcome of the two processes seven data points into the future.
Now try to predict the future. Which process will be larger in seven more data points into the future? Write your answer down.

Now, because I have chosen a very special example, there is actually a mathematical transformation that will “linearize” these two sets of data precisely. The data is exactly the same in these two new graphs. I have been able to transform the non-linear model into a linear model very precisely thanks to a very special mathematical transformation.

Here are the two linear graphs.

Now tell me which Process will be greater seven data points into the future? Carefully extend the two straight lines seven data points into the future.

Unless you are very unusual you will now get a different answer.
Most of us would predict Process 1 would be the larger in the future from either the original non-linear graph, or its inaccurate linear approximation.

But, as you see from the accurate “linearized” model it will actually be Process 2 that is the larger in seven more time units.

Now, I will show you the three graphs of these two processes for the fourteen time units, seven past and seven future.

This is the actual process and what happens. As you see Process 2 is larger at time 14.

Next is the linear version which is not really a good approximation, but often similar to the best we can do. You can see it is really quite different from the original seven point version which gave a really bad prediction. It’s still lousy.
Now we come to the linear version that is accurate since it is the same data. It is the result of a mathematical transform that is usually not available. Generally, one can’t find an accurate linear model to match the data. This is an exception that was rigged up to demonstrate a point.

Your thoughts?

Surprised?

If not, either you are a genius, or a trained mathematician, or someone I would be concerned for if you embark on a career in either science or business.

Of course, this example was contrived to demonstrate the point.

In the real world things are often much worse. Often, it is simply not possible to find an accurate linear model to approximate the better non-linear one. Sometimes, you simply can not predict the behavior of a non-linear model with anything short of a computer simulation.

And, if your non-linear model has a lot of variables and data points this can be very challenging or impossible for any computers available to you, although this is improving thanks to Moore’s Laws.

And now, a little known, truly insidious problem.

Many non-linear systems lead to a behavior known as “chaos”. In this situation, future behavior is impossible to predict no matter how good a computer you have.

In chaotic behavior, one experiences a phenomenon known as the “butterfly effect”. Small actions or inputs today can have very large unpredictable consequences in the
future. This is due to the exponential growth of the processes coupled with feedback, known to mathematicians as the Smale or Poincare effect, and called “chaos”.

Here is a simple example where this happens. A pendulum. There is an accurate math model of the pendulum’s motion which is non-linear because it involves Sin(A) where A is an angle. It is very difficult to solve the resulting non-linear math model. So guess what scientists did? They replaced Sin(A) with A in the math model. Why? Two reasons. One is that Sin(A) and A are very close and nearly equal for small angles, A. Second, they can solve the math model when A is used, since it is now a linear model.

So what? Well it turns out that under certain conditions the motion of the pendulum becomes chaotic. This is true in the real world and is true with the non-linear model. But, it is not true for the linear model. The linear model can never predict this chaotic behavior. So if you are dealing with the behavior of the pendulum in a region of its behavior where its movements become chaotic you will be very wrong with your predictions using the linear model.

So what are other situations where this type of situation can occur?

Unfortunately, just about any science or business situation you will ever deal with in the real world. We are living in a world where many of the processes we deal with are non-linear in nature. In fact, anytime we have processes with both exponential growth and feedback, we are dealing with a dynamic process that might exhibit unpredictable “chaotic” behavior in certain situations. This is true in both business and science. And, unfortunately, this is the situation often enough to reap havoc with our predictions occasionally. And, it only takes once to derail a project. The history of both science and business is replete with examples.

By the way, the above example I presented only involved exponential growth without the feedback. That is why I could solve it with a transformation that made it linear and, thus, predictable. It was not a chaotic process. Unfortunately, in the real world that is sometimes not our situation.

So, where does that leave us?

What should we do?

What now follows is my opinion and philosophy. You must ultimately decide for yourself.

First, realize what we are dealing with. Realize we are living in a sometimes non-linear and occasionally chaotic world and that the outcomes, no matter what we do, are sometimes unpredictable.

It’s fine to set goals and missions. But, don’t be too disappointed or discouraged when your plans don’t work out the way you wanted. In some cases, they won’t.
One of my favorite sayings is “Man plans, and God laughs”. This is my way of recognizing the unpredictable nature of the world we live in.

Don’t define success or failure by the results you get when you engage in whatever process you engage in. I know this is very difficult, since many of the other people in your world will make such judgments. Well, that’s life. But, you had better create a strong sense of who you are and value your efforts by your own standards and not those of others.

Focus on the processes you are engaged in. Judge yourself by how well you work in and on the processes, not just the results. Chances are you will not get the results you planned or desired very often. Sometimes better, sometimes worse.

A scientist may engage in a lot of work, either theoretical or experimental, and end up with few results that were desired to show for those efforts. Judge your participation in the process for your own peace of mind and self esteem, not the results.

It’s true you won’t win the Nobel prize without the results. But, that’s life. There is quite a bit of luck in winning such a prize. Some great scientists don’t place much stock in such prizes. They judge themselves by their own work, not necessarily their results.

Einstein won the Nobel prize for his contribution to a subject (the photoelectric effect and Plank’s constant) that grew into the Quantum Theory which was a theory Einstein was very dissatisfied with and tried to sort of overthrow in the final decades of his life. The theories he was proudest of and which revolutionized our world view were his two Relativity Theories. The first (Special Relativity, 1905) revolutionized our conceptions of time, space, energy, and matter, and overturned the views of Newton and all preceding human beings. That’s all! The second (General Relativity, 1915) extended the revolution by including the effects of significant mass on space time, i.e. gravity. Euclidean geometry was overturned in the process. No Nobel for either of these.

Einstein didn’t ultimately achieve the results he desired. He was unable to unify the two competing theories, his Relativity Theories and Quantum Theory, which are essentially contradictory. To this date (2006) no one else has either. It’s the great unsolved conundrum of physics. More on this in another musing, perhaps.

So, what’s one to do?

I prefer a Zen approach to life. Enjoy the processes you are engaged in. Live in the “now”. Don’t worry too much about results, which are often unpredictable. I personally have had many more “failures” than “successes”. But, I enjoyed the processes just as much with the failures as the successes. Sometimes more.
Most important of all. Realize that the results of your decisions may be difficult or impossible to predict very far into the future. Monitor the situation and be ready to make corrections as the process and future events unfold.

Do your best and realize our limitations.

Don’t be surprised or frustrated by unexpected results.

Be happy to be engaged with the process.

Don’t be too judgmental in labeling your results as successes or failures. Think Yin and Yang. Practice Zen and Tao.

As an old basketball coach I knew used to say, as he drank his bourbon after each game, “I’s celebrates em all the same, win or lose.”

As another great coach once said, “You might be surprised to learn that I never discuss winning or losing any game with my teams, only playing to our potential. If we do that, we should feel fulfilled and be content. I do and am.”

So he focuses only on the process, not the results.

Good advice to live our lives by in this chaotic world we find ourselves in.

Good luck.

Merry Chaos. (It’s near Xmas as I write this.)

And, Remember My Motto: Never be Satisfied, Always be Content.