

Title: Teaching and Learning by Thinking out of the Box

Abstract: This talk is about science, engineering, technology, and people. These are the ingredients that must come together to support the growing complexity of today's global challenges, ranging from international security to space exploration. As scientists and engineers it is essential that we develop the means to put our work into a decision context for policy makers, otherwise our efforts will only inform the writers of textbooks and not the leaders who shape the world in which we live. This means we must approach the educational experience in new ways! Scientific and technical progress requires interdisciplinary teams because it is impossible for a single individual to have enough knowledge to solve many of today's problems, e.g., mapping the genome, modeling the spread of a pandemic, developing diagnostic and treatment devices for developing countries. A principle role of the engineers is to bring the cutting edge of our fields to these problems. Today's education must prepare engineers to assume the role of science and technology integrator. This talk will motivate these education needs and give some ideas on how to accomplish the goals.

INTRO

This is an exciting time to be an engineer and scientist. I am using these words in the broadest way, in includes mathematics, computer science, statistics, chemistry, civil engineering, social science, art, and even humanities, etc etc. There are aspects of scientific discovery and technology innovation in all of these fields.

Global challenges problems are harder and more complex that ever before with the need to integrate:

- theory
- computation
- experimentation
- disciplines
- information of all kinds

The scope of the challenges is like never before, from ... to :

- National security, including homeland defense
- global climate change
- international economic success or collapse
- space exploration
- bio-medicine
- Zero emissions!

Message: It is simple – there is NO box, have NO fear, and know that scientific and engineering excellence will win!

I am not claiming that “win” will be easy, but if we step up to our responsibilities, it will win. Now let me explain how.

SLIDES SET_UP

I have come from an institution, one that you are all aware of, that embodies this exciting and challenging pace of science and engineering. An institution that embraces some of the hardest global challenges that exist and have existed historically since the era of the Manhattan Project.

At the heart of Los Alamos' mission is science serving society --- what makes this happen is the people, just like you and I -- Science/Technology/Community.

Today I represent Rice University, an institution I can come learn embodies a spirit similar to Los Alamos National Laboratory. From basic science to technology deployment, the faculty and students at Rice University are focused on advancing our state of knowledge and making the world a better place. EWB is a shining example of Rice's commitment to society. RWB is where it starts!

TALK OVERVIEW

Yesterday

Today

Tomorrow

DO SLIDES UP TO DEC. Piece

DECISION CONTEXT

I believe science and engineering is about improving society!!! As scientists and engineers it is essential that we develop the means to put science into a decision context for policy makers --- otherwise our efforts focused at better understanding society will only inform the writers of textbooks and not the leaders who shape the world we live in.

- A famous 1939 letter from Einstein to Pres. Roosevelt about the importance of a new energy source --- Uranium --- is an excellent example of science and engineering interfacing with policy. It changed the world forever.

However, thinking in this way points to the fact that the SCIENTIFIC PROCESS has to deal with more than executing the SCIENTIFIC METHOD:

- Observation,
- hypothesis development,
- prediction,
- experimentation
- Iteration

Things like arrogance and political agendas --- components that are NOT taught as part of the scientific method --- do enter the scientific process.

It is true that decisions will always be political and in the hands of the policy makers. As scientists it is not our task to make those decisions, it is our job to bring to them the sound science, in ways that are relevant, to assist in their decision processes.

PEOPLE

Science is about people. More than ever before science is about people collaborating toward a common goal. Scientific progress today comes about through assembling the right talents and working together.

The problems we must deal with frequently require interdisciplinary teams. This is because the scientific breadth and depth in any one field has grown to the point that it is nearly impossible to have enough knowledge from individuals in one field to solve today's problems, e.g., mapping the genome or modeling the spread of a pandemic, various disciplines can handle pieces of these problems, but the significant problem solutions are only able to come together through interdisciplinary efforts.

For example and speaking as a statistician, it is the job of my field to bring the cutting edge of statistical sciences to the problems we participate on and to communicate this to our science colleagues, such that they do not need to become specialists in statistics. The complexity of societal problems today requires that great depth in many fields come together to find solutions. No single person will be an expert in enough fields – hence we must reach out in interdisciplinary ways.

An interesting aspect of being an engineer is that we are frequently viewed as the “neutral” party on the team and hence naturally assume the role of the integrator of the science and technology!! We are problem solvers, grounded in real problems – albeit seemingly impossible ones, systems thinkers, willing to find “work arounds” until something better can be done. “Bench-to-bed” We are energized by seeing our theory our designs our ideas put into practice.

Innovation and Invention R'US

- Zero emissions (who ever expected us to get to six sigma!) –
- nano --
- revolutionary medicine –
- globalization

Various disciplines are not the only talents that must come together, other skills within those must be called out and used to work in a teaming environment.

Recognition of this is important. For example, some of you are good at:

- theory
- computation
- big picture thinking – synthesizers
- meticulous detail work
- verbal communication – written communication -- to technical work – of high level visions
- jumping into the middle of a problem
- needing to start from first principles
- organization
- etc

Likely you are not good at all these things, or find you simply don't like to do all these things! That is ok, as long as you take a healthy view that all of this is equally important for the success of the science, bring them to the table, and share credit!

TECHNOLOGY

Let me say a few contrasting words about technology. Technology is an interesting animal. Good technology doesn't always win!! Beta-max is a good example.

Nevertheless, the integration of science and technology is key for the continual forward movement of society.

Technology frequently drives the scientific process, both politically and within the scientific method. By design, technology comes to science in search of questions.

- Consider the advent of massively parallel super computers with over 6000 processors running at rates of 100 teraops – that's cool, but WHY?

The existence and potential emergence of new technology tends to create expectations of being able to answer tougher and tougher questions.

- That compute power should be able to allow us to evaluate the reliability and performance of complex aging nuclear devices without integrated experiments, but through the development and validation of gigantic computational models! hmmm validate without dead-on experimental data???? Or this compute power will allow us to estimate global climate conditions 200 years from now --- how do we know for sure?
- Imagine a nanowire that will connect the world. Next week? Next year? At what cost?

TECHNOLOGY Process:

- New Technology
- Ability to Ask Tougher Questions, Plus expectations that tougher questions will be answered
- Identification of Previously Intractable Problems
- Development of New Methodologies to Address These Problems
- Development of Theories to explain results

Once these tough questions are posed, scientists must search for methodological and theoretical justifications. Good science and engineering will ferret out if and how and in what time-frame these questions can be answered. **STAY THE COURSE!**

ROLE OF ENGINEERING

What is the role of engineers and engineering and technology in these complex problem domains being driven by the expectations of technology? Over time our role has been changing from an expert designer/technology guru to a scientific partner.

I like to think still think of engineers as the keepers of the scientific method.

- Observation,
- hypothesis development,
- prediction,
- experimentation
- Iteration

Historically this meant designing experiments and data or observation collection schemes coupled with the appropriate analysis methods to address the scientific hypotheses being posed.

Today this tradition, guarding the scientific method, continues. However, the nature of the scientific method has changed and we must now be able to develop complex decision strategies that can be supported through scientific discovery. This discovery is presenting us with new and dynamic data types coming from

- theoretical models
- computational models
- physical experiments
- observational information, new and historical
- expert judgement

These data, that must come together in a single problem formulation, may be extremely heterogeneous and diverse with respect to what types of responses they represent. The problems we consider today have huge policy implications == which brings be back to EWB!! What could be more exciting!!!

END PIECE

I encourage you to always keep scientific and engineering excellence in your sights, it does matter and it will win! We are the people in the people/science/technology integration process and only through working together can we credibly allow science to make a difference for society.

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