The Ingenuity Imperative

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When I looked carefully at the attendance list for this conference, I realized that a number of you have been at this conference every year, for the past ten years, as I have. For the last decade I have had the pleasure of working with many of you as we attempted to create a better, technologically-savvy Texan. But I think few of us really understood the future importance of our work as rapidly evolving technologies created an increasingly complex tomorrow. The future really is the result of the choices we make today. What we decide and do, today, actually matters to history and will determine the landscape for decades and centuries to come. I have something important to share with you today about the future of technology education in Texas.

Ten years doesn't seem like a long time, but let's quickly look at what has developed since 1995:

Cell phones

Wireless internet

Hybrid cars

PDAs

MP3 players

The Genome Project

Viagra

Lipitor

Stem Cell Research

Nanotechnology

Genomics, proteomics, bioinformatics

The presence of water was discovered on the moon

The presence of life on Mars

DVDs

The Hubble space telescope

Smart weaponry

The Boeing 777 was designed

Pixar created the first computer generated full length feature film "Toy Story"

Intel released the 200 MHz Pentium processor

Internet fraud and viruses

Biological imaging

Did you prepare any of your students for these changes and new technologies?

Our world has changed more in the last 100 years than in all the preceding years of humanity. We are healthier, safer, and more productive. We live in a world dominated by a single species' technology and not nature. We have longer, healthier lives, improved work and living conditions, global communications and travel, and unparalleled access to art and culture. This is true for most of us in the developed world, not just a privileged few. Of course, most of the people of the world do not benefit from these advantages and it will be the challenge of future generations to spread the positive aspects of our innovations throughout the world.

We all want to know the future; we try to predict what the world will be like.

As educators, we try to prepare students for a world that is unknown. To be frank, we provide to the students knowledge, skills, and dispositions that were valuable during our time, decades ago. I ask you, is this strategy in our best interest, to prepare kids for our past? Or should we try to envision our students' world and revise our curriculum to prepare them for this future?

What do you think the future, 2020 will look like?

Let me show you one of my favorite movie clips from the original H.G. Wells movie, The Time Machine. This scene captures the essence of what I am talking about.

Hold on to the following thought, "Which three books would you take into the future to build a new civilization?" What enduring knowledge would you carry into the future to build a new world? Is it what you are currently teaching in your class? I hope you capture the importance of what I am saying. Our world will

be dramatically different in the next decade. How are we preparing the kids of today for the decisions of tomorrow?

What will the future look like? What do you think the next decade will bring? Let me share a few things we know are on the horizon.

The future will be filled with exciting breakthroughs in human physiology. Working at the cell level, diseases that we know today will be eradicated. The effects of aging can be reduced. Tissue engineering and regenerative medicine may lead to new technologies that will allow our bodies to replace injured or diseased parts without invasive surgery. Rather than the barbaric equivalent of running a sewer snake through our arteries, nanobots will clean our clogged and blocked arteries. Drugs will be customized for each individual. Embedded devices will aid in communication and monitoring our organ functions.

Nanoengineering will create and manufacture structures at the molecular, even atomic level. Environmental cleaning agents, chemical detections agents, the creation of biological organs, nano electronic systems, and ultra fast, ultra dense electrical and optical circuits will result from nanoengineering.

Our perceptions of connectedness, location, and access will change as the world becomes more connected electronically. Everything will become smart. Every product, service and system will be directed at meeting the needs of the humans it serves and will adapt its behavior to those needs.

In 2019 a $1,000 computer will have the computing capacity of the human brain. In 2029 the same computer will have the computing capacity of 1,000 human brains. In 2039 the computer will claim to be conscious and self-aware. These claims will be largely accepted.

We will struggle with those who attempt to use new chemical and biological discoveries as weapons. We will need a better understanding of the transport characteristics of biological and chemical agents.

The United States has probably the best physical infrastructure in the developed world. But these systems are degrading rapidly. Our water treatment, waste disposal, transportation, and energy systems are in serious need of replacement and redesign.

As we depend more on the information infrastructure it becomes more vulnerable to accidental, terrorist, and malicious attacks. This will impact our national economy, national security, our lifestyles, and our sense of personal security. At the same time issues of privacy and access have to be addressed.

In the next 20 years, every nation in the world will face some type of water supply problem. Currently, 2 billion people live in conditions of water scarcity. Water supplies will affect the world's economy and stability.

Ecological sustainability must be a consideration as we develop new technological solutions to the problems we create if we are to have economic prosperity. Green engineering, the design, commercialization, and use of processes and products must become mandatory if we are to mitigate the risks to human health and the environment that we have created.

What we know about science and technology today will double in 10 years. It will become increasingly difficult for us to understand the total body of knowledge of a field. The notion that a person learns everything he or she needs to know for a life-time in a four-year degree is not true. It really never was. You and your students will need to accept the responsibility for re-educating yourself.

When engineers begin sketching a design they do it not only with a foundation in the sciences, they also use the tacit knowledge gained from their experiences. Tacit knowledge is grounded in objectivity. It is the knowledge that is gained by doing, not imagining. Tacit knowledge and experience prevent us from wasting energy on fanciful ideas that violate known scientific principles. Western society values its deep scientific understandings. In fact, we judge our national prowess by the strength of our scientific discoveries and the rate at which we accumulate knowledge. We also value the discoveries of the humanities, whether by poets, painters, writers, or dancers. In fact, we consider these successes to represent the height of human endeavor. But, for a variety of reasons, we don't value the contributions of the ingenious, the innovators, nor the inventors. While their work is not in the direct pursuit of

> Civilization, as we know it today, owes it existence to the engineers. These are the men who, down the long centuries, have learned to exploit the properties of matter and the sources of power for the benefit of mankind. By an organized, rational effort to use the material world around them, engineers devised the myriad comforts and conveniences that mark the difference between our lives and those of our forefathers thousands of years ago.

The ingenious, the innovative, the inventive are driven by a deep passion to conceive new technology, to build it, and to make it work. Innovations and inventions occur when a need arises or an opportunity presents itself. Science rarely translates into technology directly. Many advances of technology occurred before we knew about the science. But this is a model that is now no longer valid. Human-made artifacts are now principally designed through rules, principles, and predictions rather than trial and error. Today we find that the work of scientists and engineers are growing closer together and are sometimes indistinguishable. The thrill of the scientific discovery and the engineered creation are intellectually challenging and satisfying.

The goal of science is to discover the laws of nature and understand its behavior. The goal of engineering is to create technology that meets the needs and wants of humanity. "Science deals with what is, comprehending nature as it exists; engineering focuses on the future. It creates new material environments, producing products, processes and systems that did not previously exist." (Lewis, 2004)

I see three overwhelming threats to our American way of life that I believe, we as technology and pre-engineering educators can address through a single strategy: Ingenuity Education.

The first threat is related to human and technological growth. The world population is, as we know, increasing and the problems created because of this growth are complex. Energy themselves, create unanticipated problems which are often more complex than the original problems. So, we have technological growth problems and population growth problems.

Problems require human ingenuity, innovation, and inventive solutions if they are to be sustainable. There is a possibility that we may be approaching an "Ingenuity Gap." As population and technological growth increases, new complex problems are created and there may be a point at which we will not have the inventive, innovative or ingenuity capabilities for solving them.

This is an interesting concept for us to grapple with because we've always believed in "Yankee Ingenuity" and how we would always solve whatever problems were encountered. Looking around the world, we already see many countries where the creative workforce capabilities are not sufficient to solve its current problems. The only solution for these countries is to import the intellectual capabilities.

The "Ingenuity Gap" theory, developed by Thomas Homer-Dixon is an alarming conceptualization and potential call to arms for education. We've always been able, as a nation, to develop more solutions than problems. A significant part of the American high quality of life is related to innovation and ingenuity. But, we may be approaching a point, somewhere around year 2020, when we might we are unable to solve our present problems. That is, when our present intellectual capabilities are insufficient for solving the new problems. We would have an "Ingenuity Gap." The "Ingenuity Gap" is a critical theory that we must consider now if we are to "head off" its devastating consequences.

The second threat is a new division of labor. Many current jobs are being replaced by automated machines and low-cost labor. We teach about the effects of automation in our robotics classes. The secondary and postsecondary education system was unprepared for the rapid changes in the labor force as a result of the application of information and computer technology. Many of the jobs we are preparing students for are no longer available. If they are,

they are low-paying non-family supporting jobs. Information and computer technology have dramatically impacted the way in which we work. Electronic communication technologies have allowed many jobs to be completed in distant, offshore locations. When you call a company for their 24/7 service, it is not that a single location is staffed 24 hours a day. It may be that, in different time zones around the world, there's another shift worker processing your request. I think we are ignoring the profound effects this will have on sustaining a high quality American lifestyle.

Outsourcing. What's your the number one complaint when you go through a fast-food restaurant drive-through? You get the wrong order or you're missing something! You've learned to open the bag and check to make sure you got all your fries and burgers. Did you know in St. Paul, Minnesota that a national fast food restaurant is experimenting with outsourcing the order taking process? When you drive up to the window, to the little box where you speak your order, that the person talking to you is not located in that building – he/she is in North Dakota. You give your order to the person in North Dakota who then transmits it to the food preparers in the building. Why, you might ask: in order to increase reliability and give greater customer satisfaction. It probably won't be too much longer before they find it can be done in some place cheaper than North Dakota.

I think we are experiencing a massive redistribution of labor and probably a redefining of the American way of life that we need to pay attention to. This new division of labor is going to be based on two concepts. One is rule-based, procedure-based jobs that don't require creative solutions, are easily programmed, easily outsourced and easily automated. All that is required is to follow the procedures, follow the flowchart. Notice that when you call technical support for you new appliance that they ask you a series of questions. Once they get to the end of their script, so to speak, they'll transfer you to the next level of technical support, to somebody with new script of questions. Its mass production type work with limited thinking and absolutely no creativity required.

The second division of labor will be the creativity, innovation, imagination and ingenuity-based jobs. These are high-value, economy building jobs. They are high wage jobs that support a high quality of life. The economic function of creative talent is to generate new ideas, technologies, and solutions. I think there is an impending creativity crisis that will lead to a national "Ingenuity Imperative." We really need to look at the issues before us. Creativity-based jobs include scientists, engineers, architects, designers, educators, artists, musicians, technologists, leaders, managers, business people, finance people, lawyers, healthcare professionals, communication specialists, and the entertainment sector. These are the people that use their minds to develop new solutions to current, new, and recurring problems. We should be alarmed at the shrinkage in the American creative talent pool.

The third threat – security and safety – is one which I heard from Congressman Vernon J. Ehlers, and I think it is very important for us to consider. The issue is homeland security. He stated very simply, "Those we educate today will protect us tomorrow." The military requires an increasingly sophisticated soldier. Counterterrorism will require more advanced capabilities if it is to win the war on terrorism. The destructive radical innovator/inventor must be minimized. What are we doing to foster the intellectual capabilities of our youngsters to protect their futures?

What are we to do? The American creative talent pool that feeds the high tech, high margin industries is, in fact, shrinking. New talent, if we're looking at it from that perspective, is not sufficient for the future demands. Innovation education is, tragically, not a part of the American public education system. I had the opportunity to talk with several technology educators from New Zealand who indicated New Zealand had made innovation education a part of its national economic development plan. It's a part of New Zealand's strategy for survival, sustainability, and economic growth.

Let me suggest two solutions for your consideration. First, we need better technological planning and decisions based on technological literacy. Reconsidering the "Ingenuity Gap, we may be creating more problems than we can solve and the adoption of some of the technologies that we create should be reconsidered or even halted. This requires an informed decision maker and the current education system does not provide opportunities for students to become technologically literate. The citizens of the

choose to develop or use a plethora of new technologies.

Second, we should also think of creating better technology through increased ingenuity, innovations and inventions. Good decisions about technology I think are important, but it is not enough. Engineers and technologists are those prepared to imagine, design and build a better world. We and our societies change with the diffusion of technology. We don't understand what's happening and we don't even see what's happening until it actually happens. So, we need to understand the place and role of existing and new technologies in their social organizations as well as their future impacts on society as a whole.

I developed the concept Five Pillars of Technological Literacy, which I believe support sustainable technological and economic advancement. These are characteristics that I would like to see evidenced by all kids: (1) I want a kid who walks into a situation and says, "I can solve this. I'm not afraid of this technology." We refer to this as technological self-efficacy. That's the kind of kid I want working for me or preparing for my future. (2) I want kids that can say, "I've made a good decision." They have a rational decision-making process. They've actually thought about not only the process but the decisions they've made. (3) I want kids that say, "You know, I understand the issues of technology. You know, I do understand the science also, and I do understand the social impacts that are related to this." I refer to this as pre-requisite knowledge and skills. (4) I want kids that can say, "This is a good application. We chose the right technology for this problem." So, there's critical application. (5) And certainly we want kids who are able to say, "Let me rethink this. Let me make sure that the solution that I created, that I adopted or adapted or invented is the right one." They reflect on why they did what they did in order to make sure that it was a good decision, and to try and improve their own thinking processes. The Five Pillars of Technological Literacy are dispositions which are important for us to foster in our students. Technological literacy supports these characteristics.

ing. Second, one can adopt what others have done. One does a search of how others have solved the problem. This is a part of our problem-solving methodology. Third, one can adapt a solution. One looks at what others have done and says, "That doesn't quite fit; let's tweak it; let's modify it; let's be innovative; let's change it just a little bit and it will meet our needs." The fourth option is to invent a new solution. The ability to adopt, adapt, invent and evaluate technology to positively influence the community and the environment is what technological decision-making encompasses. The ability to consider these decisions options is a fundamental part of a technologically literate society.

The ingenuity component of my solution is something new. As you know, there's tremendous effort – millions and possibly billions of dollars are spent for science and mathematics education. We need new solutions and better solutions, and increased math and science capabilities are important. But, I ask you, if we have already spent millions and billions of dollars in trying to increase math and science education as a solution to this problem, why are we in a creativity crisis? Why are we in a situation where America is no longer the world's innovation powerhouse? I believe we find ourselves in this situation because mathematics and science education are directionless. Without coupling these capabilities to the creative abilities of our students we will continue to lose dominance as an innovation nation. Ignoring the ability to be innovative, ingenious and inventive is a tragic and potentially catastrophic mistake of our public education policy. Science and mathematics education is only one aspect of this sustainable economic future. Innovation, ingenuity, and inventiveness must be a part of every child's education. It is something we can contribute to as technology educators.

I think we are at a critical moment in American economic history. A tremendous amount of money is being spent once again for mathematics and science education, which is critical to the development of new technologies. The old trial and error method that we used (what I affectionately refer to as successive

approximation which sounds much better than trial and error), has left us with a creativity crisis. We have no nationwide plan for K-16 innovation, ingenuity and invention education. I think we need to act now on this issue. We as informed and concerned technologists and pre-engineering educators must embrace this opportunity to build a better world.

An interesting book *The Engineer of 2020 – Visions of Engineering in the New Century*, released by the National Academy of Engineering (2004), confirms my supposition on these items. The NAE wanted to see how they could foster change in engineering education and suggested several attributes of a 2020 engineer. Look at the first three attributes they identified – (1) strong analytical skills, (2) practical ingenuity, and (3) creativity (i.e., innovation, invention, thinking outside the box and art.) How's that! Gee whiz, isn't that something that we do in our laboratories and classrooms? We teach kids how to plan, how to combine, how to adapt things to solve problems. These are the attributes the NAE thinks are important for engineers in 2020. I think these attributes are important for every citizen in the United States.

This is Technology Education's decade. This is the decade when we will make a difference in public education, and I wonder, will we seize the problem and solve it by what we know, by even using our own innovation and ingenuity? Will we, instead, protect our past, or will we do nothing? This is our decade to lead the nation to a better tomorrow. So, I ask you to join us in unleashing your own ingenuity, your own innovative and inventive capabilities as you instruct future generations for a better world.

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