STEM Teacher Training at Hillside Grammar School

By
Harry T. Roman
Inventor, Author, Teacher

Implementing a STEM Grant

- Teaching STEM in support of a Bristol-Myers Squibb Grant for Teaching Excellence
- Enhance students' application of STEM skills in a real-life context…develop a unit that involves invention, sustainability, and STEM skills as well as provides for professional development for science teachers that facilitates collaboration as a professional learning community.

Topics of Discussion

- Invention-Overview
- Understanding Invention
- The Invention Notebook
- Integrating the Curriculum Using STEM Principles
- Critical Skills for Success
- About Engineering
- Sustainability-Renewables

Invention-Overview

About R&D

- R&D is the activity that converts "uncertainty into risk". Business will "bet" on risk. R&D is similar to "due diligence"—i.e. reduce risk.
- Patents are often the natural outgrowth of R&D and new product development; and represent "crystallized technology", developed for commercialization.
- R&D is often conducted via a portfolio or suite of technologies, much like an investment fund.
- Often these suites of technologies are inter-related, synergistic, and strategic to a company.

Technology

- "The know-how to convert what we have [i.e. resources, people, time, money…etc.] into what we want and need." [Julian Simon- U.S. economist]
- Patents represent our know-how captured in a formalized language and format. Our patent system is a library of technological know-how.
- Failed patents serve as a scrap-yard or recycling center for new ideas/technology.

Invention is:

- Interdisciplinary
- Multidimensional
- Team-based
- Iterative
- Usually messy
- Can be serendipitous
- Highly relevant to STEM education in schools

10 Characteristics of Successful Inventors/ Innovators [source: Inventors Digest magazine]

- 1) Persistence
- 2) Passion and intellectual curiosity
- 3) Independent minded-willingness to go against the grain
- 4) Ability to recognize and combine patterns into new ideas
- 5) Intuitive yet analytical-ability to understand and interpret business data [cont'd next slide]

10 Characteristics of Successful Inventors/ Innovators [source: Inventors Digest magazine]

- 6) Ability to sell ideas and concepts
- 7) Focused on the future
- 8) Ability to draw on wide networks for perspective, advice and accomplishing tasks
- 9) Tolerance for risk and ambiguity
- 10) Willingness to fail and learn from failure

Relevance to STEM

- Invention involves science, technology, math, and engineering-integrating the academic day.
- It also involves looking at the impacts of all this on society, culture, the environment…etc. – a global outlook.
- Invention and STEM strive to achieve blended, mediated, or integrated solutions…just what engineers strive to do. Engineering can be thought of as "designing with constraints."

Interesting Statistics

- According to Du Pont, it takes 164 raw ideas to result in 4 that are capable of making money.
- About 65-70% of all patent applications result in an issued patent. Only 2% of those issued patents result in commercial success.
- About 70-75% of new product failures result from a breakdown in corporate teamwork and communication.

Understanding Invention

Invention-the Natural Activity

- Everybody invents
- We do it without thinking
- Our brains are “wired” for it
- Invention is a way of thinking…..a process….very similar to STEM education

Invention is ……

- Done to solve a problem/need
- Organized and planned….a process
- Team activity and creativity
- Uses all subject knowledge..blended together
- Filled with failure and dead-ends
- Often surprising and great fun!

The Invention Process

- 1) Identify a problem worth solving
- 2) Evaluate the economics/market needs
- 3) Identify constraints, impacts, challenges
- 4) Identify/test potential solutions…invent!
- 5) Validate invention against 1), 2) and 3)

  [repeat 1) thru 5) if necessary]
- 6) Market the invention
- 7) Improve and grow the invention

Edison's View About Failure

Always learn from failure……

"Fail Your Way to Success!"

New Jersey is a Patent Leader

[top ten, rank order, 1977-2010 data; source-US PTO]

California	446,523
New York	177,406
Texas	145,583
New Jersey	**115,637**
Illinois	115,602
Michigan	105,502
Pennsylvania	103,152
Ohio	102,513
Massachusetts	94,320
Florida	73,798

Invented in New Jersey

- Phonograph, motion pictures, light bulb and electric utility industry, R&D labs…all by Edison.
- Solar cells, Transistor, Cell Phones,
- Fiber optics, Lasers/masers, FM Radio,
- Telegraph code, Liquid crystal displays,
- Many important health drugs, Lubricants
- Sunscreen, Bubble wrap, FAX machines,

Invented in New Jersey [cont'd]

- Radio astronomy, Chlorination of water
- Electron microscope, Lithium batteries
- Photographic film, Twin hull submarine
- Hovercraft, Many integrated circuit designs
- Modern detergent/cleaning agents, Golf tees
- Ice cream cone, Baseball catcher's facemask
- Packing and shipping tapes, TV picture tubes

Invention and Our Standards of Living

- Inventions have made our modern world possible
- Over 70% of our economy….driven by science, technology, invention
- Inventions plus market focus = innovation = progress

U.S. Patent Statistics

1792	0	Doubling Time
1911	1,000,000	
1935	2,000,000	143 years
1961	3,000,000	
1976	4,000,000	41 years
1991	5,000,000	
1999	6,000,000	
2006	7,000,000	
2011	8,000,000	35 years

The Invention Notebook

What is an Invention Notebook?

- A chronological diary of the inventor's ideas, experiments, analyses, and ruminations about the development of the invention
- This notebook reduces the basic idea of the patent to practice
- It is the prelude to writing a patent disclosure or a full patent

What an Invention Notebook Contains

- All relevant information about the invention including drawings, sketches, schematics, diagrams….etc.
- Calculations and mathematical formulations
- Lab data, experimental results/analyses
- Discussions/conclusions
- As much relevant information as possible

Invention Notebooks are Legal Documents

- Establishes the priority of the work of the inventor
- Has standing in a court of law
- Entries in the notebook should be witnessed and counter-signed by colleagues in the lab or within the organization where the work is being performed.
- Invention notebooks are similar to scientist lab notebooks

Teaching Students About Invention Notebooks

- Foster better communications skills-clear and concise writing
- Build planning and organization skills
- Foster appreciation of the discipline and process of invention—organized creativity
- Infuse a disciplined approach to thinking and reasoning
- Motivate students to learn more about inventing

Integrating the Curriculum Using STEM Principles

About STEM

- What does STEM mean to you?
- Is it similar to the post-Sputnik era of science and technology change of the early 1960s?
- How do you feel about the way it could impact the way you teach?
- How do you feel about teaching it, or using its techniques?

Timelines

- Examine how trends/actions/events interact over a defined period….say, a decade.
- How did the Internet affect our:
  - Economy/business sector
  - Science/technology
  - Music/art
  - National security/government
  - Society/politics
  - Environment
  - Language/lexicon/words?

Examine Technology and the Arts

- How have technological advances impacted the arts?
  - Video/animation/special effects
  - Automation of stage plays
  - Music/sound recording
  - You Tube!
  - Paints/art supplies
  - CDs/DVDs/HD TV
  - Other impacts?

Play "What if" Scenarios

- Challenge students to identify and appreciate broad change….. "what if"….

  -All nuclear plants were closed

  -Internet use was taxed

  -People work at home via computers

  -All new cars must be electric/battery powered

  -Other?

Explore Science Fiction

- Science fiction offers a rich landscape to explore how technology and science and culture interact

  -It is a literature of change

  -Examines how societal change occurs

  -Often predicts where society is headed

  -Great works of literature were about Sci-fi

  -Have students write short sci-fi stories

  -Watch sci-fi movies and discuss

Re-design the Academic Day!

- Unleash your students to re-design the academic day:
  - -Teach about the math in music
  - -Break day into hands-on studios
  - -Make teamwork essential for all projects
  - -Explore commonalities of
    - science
    - art
    - invention

Check out Technology Education

- The study of the human-designed world that:
  - Integrates the curriculum
  - Process and content based
  - Powerful head and hands philosophy
  - Design challenges!
  - Very similar to what engineers do
  - Business world likes this paradigm

Study Invention

- Link invention to economic growth
- Identify and study great inventors
- Examine women inventors
- Identify and define the invention process
- Link invention to good communication skills
- Identify local inventors in your state
- Invite inventors into class to discuss their world

Host Roundtables

- Invite engineers, artists, inventors, musicians/composers, and architects to a class or school roundtable discussion:
  - What are their similarities when creating?
  - How do they create?
  - Why do they create?
  - How do their creations affect society?
  - Why did they choose their field?

Study Architecture

- Architecture makes both a physical and cultural statement.
- How and why do they blend together:
  - -Art
  - -Technology
  - -History
  - -Engineering
  - -Culture?

The Robot Venue

- Using robotics is a very powerful and attractive venue to use with students.
- Kids love robot design challenges-choose real problems that can be solved.
- Unleash teamwork-based design challenges
- Have team present their work orally and in written form.

Write Poetry and Prose About

- Art
- Technology
- Science
- Architecture

Welcome student humor-a very powerful creative element!

Critical Skills for Success

The Key Skills

- 1. Analyze Information
- 2. Convert Information to Knowledge
- 3. Sell New Ideas to Management
- 4. Communicate Concepts Clearly and Succinctly
- 5. Plan for Timely Implementation
- 6. Be a Team Player
- 7. Multi-dimensional, Integrated Problem Solving
- 8. Seek Learning Opportunities

Promoting These Skills in School

- Integrate the Curriculum
- Solve problems on a multi-dimensional and inter-disciplinary basis
- Open ended problem solving
- Bring lots of math into the curriculum
- Teams, teams, teams!
- Head and hands learning
- Make creativity and invention a priority

Integrate the Curriculum

Solve problems, open-ended problems, on a pro and con basis, with a matrix that examines:

- The economy, technology, environment
- Social, institutional, and regulatory aspects
- Safety, legal, and cultural dimensions
- Government and geopolitical facets.

Blend solutions to solve problems-taking into account the above

Work with Data-Draw Conclusions

- Conduct classroom experiments
- Have students collect/tabulate data
- Use data to make graphs or charts
- Analyze the data to understand what's happening-discuss in detail
- Draw conclusions from observations and data
- Have students design their own experiments and conduct them.

Teams Are Very Important

- Assemble balanced student teams
- Let them own the problem by defining it
- Teams conduct:
  - -Research
  - -Propose and finalize solutions
  - -Reach their own conclusions
  - -Document their work
  - -Produce written reports
  - -Present their work orally

Adopt STEM Principles

- Use STEM teaching principles and techniques
- Head and hands approach to problem solving
- Bring in the math big time!
- Use technology education techniques
- Involve other teachers with your class-team teach.

Explain the Invention Process

- Identify needs or wants of customers
- Conduct research-what has been done already?
- Identify possible solutions---assess market potential
- Pick most promising option and invent!
- Identify, assess, and minimize potential impacts
- Document work and intellectual property
- Develop plans to implement
- Move to market
- Explain how the economy works!!!!

Create New Products in Class

- Brainstorm new ideas and select best
- Develop invention---keep invention logs
- Make plans/timelines for market launch
- Use math--estimate costs to make products
- Use math--estimate market size/share
- Use math--determine selling price
- Document the work
- Market the product in brochures and pamphlets

Inspiration from Thomas Edison

- Think out of the box
- Be entrepreneurial---take risks
- Fail your way to success
- Always improve your products

Study inventors, entrepreneurs, business experts, and great innovators-past and present!

Communication Skills

- Take no prisoners here!!!
- Grade all reports for accuracy and grammar
- Require re-writes when necessary
- Teach oral skills and practice them regularly
- Emphasize how grammar and speech are used to evaluate people
- Reading comprehension exercises a must
- Emphasize and practice word economy and summarization of facts and conclusions

About Engineering

Famous Quotes About Engineering

"Engineers operate at the interface between science and society."

-Dean Gordon Brown, MIT, 1962

"The engineer has been, and is, a maker of history."

- James Kip Finch, 1960

Engineers Are……

- Builders of Civilization
- Creators of Wealth
- Organizers of Society
- Agents of Change
- Leaders and Developers of People
- Project Managers
- Inventors and Innovators
- Entrepreneurs
- Continuous Learners

Engineering Equation

Science + Market Needs +
Creativity + Engineering
= Progress

America's Great Technology Cycles-Engineers Lead the Way!

- 1800-1850 - Steam power and textile manufacturing
- 1850-1900 - Railroads and steel
- 1900-1950 - Electric power, automobiles, chemicals
- 1950-2000 - Computers, nuclear power, aerospace, biotechnology, pharmaceuticals, and electronics
- 2000+ nano-technology, advanced manufacturing, green energy alternatives, life extension/advanced health issues….etc.

Recent Quote About Engineering

"Science is about understanding the origins, nature, and behavior of the universe and all it contains; engineering is about solving problems by rearranging the stuff of the world to make new things."

-Henry Petroski, 2010

Famous U.S. Engineer & Author

The Oldest Professions

- Architecture
- Law
- Engineering
- Medicine
- Military

Engineers in U.S. Workforce

- 1960 700,000
- 1970 1,000,000
- 1980 1,200,000
- 1990 1,700,000
- 2000 1,900,000
- 2010 2,300,000

Mean Annual Wage…….$77,000

Young Engineers Start…. $40,000-$60,000

Upper Range……..$120,000-$150,000

Engineers do Great Things

- Put us on the Moon
- Built our bridges and major structures
- Built and maintain all our utilities
- Protect us with national defense systems
- Harness our natural resources
- Manufacture the goods we use every day
- Improve efficiencies and key processes
- Improve our quality of life

Engineers Solve Problems In Multi-Dimensional Ways

Engineers solve problems, taking into account the implications involving:

- Technology
- Environment
- Society
- Legalities
- Safety

Engineering problem solving is exactly what STEM education is all about-integrated thinking and decision making.

The Engineering Process

Here is a glimpse of the engineering process that is used to tackle new design and problem challenges:

- Understand the Problem **and** the Market for the Solution
- Assemble a Multi-disciplinary Team
- Identify and Understand Design Constraints and Tradeoffs
- Develop a Specification for Success and Plan of Action

The Engineering Process [cont'd]

- Creatively Develop the Problem Solution or Design
- Build and Test the Prototype or Pilot System
- Critically Evaluate the Prototype/Pilot to its Constraints
- Revise Prototype/Pilot into a Commercial Product
- Launch the Commercial Product
- Continuously Improve the Product

Engineers Use Math to….

- Better understand the world's needs
- Quantify impacts/benefits of their technology
- Compare their work to alternative designs
- Determine the economics of their creations
- Explain their work to others; and put their work into perspective
- Form a basis for tracking technological success

Engineers Communicate Well so They Can

- Sell new ideas
- Clearly explain what they are proposing
- Convince technology users of benefits
- Develop clear, concise plans
- Obtain funding for technology development
- Manage and lead team members
- Report on progress

Original Engineering Disciplines

In our nation's early history, these were considered engineering disciplines:

- Surveying
- Mining
- Canal and road construction
- Military arms, defenses, fortifications, and navies

By early 1900s-Five Basic Kinds of Engineering had Emerged

- Civil
- Mechanical
- Electrical
- Chemical
- Industrial

Today, Engineering Specialties are Inter-disciplinary

- Biomedical, Prosthetic, Acoustics
- Ceramic, Materials, Manufacturing
- Aeronautical, Aerospace
- Computer, Robotics, Software
- Petroleum, Transportation, Lubrication
- Energy Systems, Solar/Alternate Energy Systems
- Nuclear, Environmental, Sanitary

There are over 100 different kinds of engineering specialties!

The Versatile Engineer-Can Easily Change Jobs if Need Be

Because of their strong problem solving skills, engineers often move into varied professions:

- Inventors
- Doctors
- Lawyers, Patent Attorneys
- Executives, Entrepreneurs
- Teachers, Professors
- Authors, Musicians, Artists

Presidents and Engineering

"To the engineer falls the job of clothing the bare bones of science with life, comfort, and hope."

-Herbert Hoover

Mining Engineer and President

5 U.S. presidents were engineers:

Washington, Jefferson, Lincoln, Hoover and Carter

Sustainability-Renewables

Sustainable Development

According to the EPA, "sustainable development" marries two important themes:

1) Environmental protection that does not preclude economic development
2) Economic development that must be ecologically viable now and in the long run

Principles of Sustainability

The principles of sustainability can stimulate technological innovation, advance competitiveness, and improve our quality of life. When we talk about sustainability we naturally think of:

- -The human designed environment;
- -Water ecosystems, and agriculture;
- -Energy and the environment; and,
- -Materials handling and toxics.

Philosophy of Sustainability

Sustainable development is both multi-dimensional and inter-disciplinary in its outlook, assessment, and evaluation.

Sustainable development blends together key concerns of the environment, society and the economy.

Examples of Sustainability [1]

- Cradle-to-grave design and recycling of computers and other appliances;
- Application of wind machines for the generation of clean electricity;
- Movement away from petroleum based automobiles-to hybrids, electrics, and fuel cell powered cars;

Examples of Sustainability [2]

- Cities and counties proposing and implementing smart growth strategies; and,
- Recycling of liquid, solid and gaseous industrial and consumer product waste streams.

Sustainability and STEM

- Sustainability meshes nicely with STEM initiatives and the study of engineering.
- In fact, exposing your students to case studies of engineering is great preparation for teaching sustainability concepts in class.

Students Should Evaluate Sustainable Options

Students should employ some basic techniques in evaluating possible sustainable options like the use of:

-Detailed pro and con statements for option[s] identified;

-Spreadsheets to list their options against possible other concerns like cost, environmental impacts, time to develop, availability of technology, use of scarce materials, capability to recycle components at end of product/ process life…..etc.;

-Figures of merit or weighting factors to determine the importance of various aspects of the spreadsheet or matrix evaluations.

Basic Solar Applications

- Solar Heating & Cooling
- Solar Electric Conversion [photovoltaics]
- Wind Energy Conversion
- Solar Thermal Power Conversion
- Biomass
- Ocean Thermal Energy Conversion

Other Renewables

- Small Hydroelectric
- River Currents
- Municipal Solid Waste [MSW]-Garbage
- Geothermal Heating & Cooling
- Tidal Power

Traditional Fuel Sources

- Coal
- Oil
- Natural Gas
- Nuclear
- Large Hydroelectric

Energy Content of Common Fuels

- Peat 1,750 Btu per pound
- MSW ~4,600
- Wood 6,800
- Coal 12,500
- Oil [crude] 18,500
- Natural Gas 23,500
- Nuclear 30,000,000,000

Energy Delivery of Solar Sources

- Sunlight: 200 Btu per hour per square foot
- Wind: 75 Btu per hour per square foot of wind turbine swept area in 22 mile per hour wind

- Solar energy sources are much more dilute in energy density than conventional systems, and hence more care is needed in designing and utilizing them.

Energy Density

Energy Density or Footprint of Energy Technologies for NJ Conditions

- Coal/oil/natural gas/nuclear: 2,000-4000 MW per square mile of land
- Solar electric [photovoltaic] 100 MW
- Wind 10-15 MW [offshore…25-50 MW]
- Biomass 1 MW

Renewable Energy Constraints

Alternate/Renewable Energy Technologies Can Be:

- Land Intensive
- Variable Due to Weather Conditions
- Dependent Upon Geographical Locations
- Must be Designed to Meet Local Conditions

The End

Questions?

Comments?