

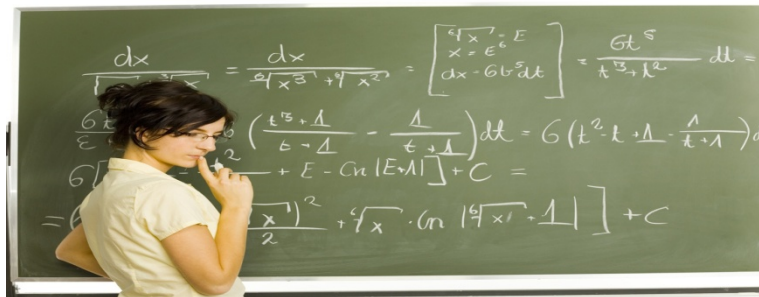
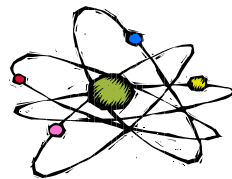
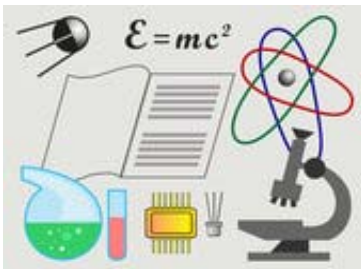
STEM—Science, Technology, Engineering and Mathematics Education for Gifted Students:

Designing a Powerful Approach to Real-World Problem Solving for Gifted Students in Middle and High School Grades

ISBN 0-910609-60-8

By Harry T. Roman

Technology and Engineering Educator
East Orange, New Jersey



Gifted Education Press

Manassas, Virginia

2011

Published By:

Gifted Education Press
10201 Yuma Court
P.O. Box 1586
Manassas, Virginia 20109
703-369-5017

www.giftededpress.com

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Preface

For most of my 36 year engineering and R&D career, I have had the honor of working closely with the academic community, lecturing in many schools in my native state of New Jersey. I often brought my research work into the classroom, sharing it with gifted students---showing them how the science, math, technology, engineering, and invention all meshed together; along with the non-technical aspects of problem solving, a most important and often forgotten aspect of STEM. Throughout it all, and even now in early retirement, I write educational documents and resource books for the classroom. I have witnessed the very early days of STEM, when the teaching paradigm of technology education took its first faltering steps in the mid-1980s; and I have practiced it with a passion, building its message into everything I write about. It is both visceral and so very obvious to me.

Here are some very important things to remember about STEM as you move through this book:

- Asking high quality questions and inquiring in depth about the problem at hand is a key aspect of the STEM philosophy.
- STEM is an integrated approach to problem solving, both on a multi-dimensional and multi-disciplinary basis.
- It often works best in student team-based situations; coupled with head and hands learning opportunities.
- STEM is an outgrowth of the highly successful technology education curricula, where head and hands are used in the study of the human designed world. It's taproot however, goes all the way back to Thomas Edison.
- It is not just for "techies". STEM can be used in any kind of problem solving situation. It is about making students think. Engineers have been using a STEM approach to problem solving for many years; as have inventors.
- STEM is not about the speed of the solution to problems (although in the business world that is good to maintain competitive advantage), but rather the thoroughness or quality of the solution.
- Math and using it as a tool of inquiry and analysis is a major feature of STEM and will give students a much better appreciation for how math is relevant and important in the world.
- It is an empowering agent to push the envelop of learning and problem solving.
- Businesses highly value employees with strong STEM backgrounds. These employees often make excellent project managers.
- Creativity and imagination are important components to facilitating STEM-like thinking.

In this slim compendium, I have woven together a variety of topics that can enhance a gifted and talented student's appreciation for STEM. I hope you find this a useful classroom resource and guide.

Harry Roman

Introduction

STEM Learning

Science, Technology, Engineering and Math, or STEM, is today's educational centerpiece. This multi-dimensional, inter-disciplinary approach, aided by head and hands thinking, is exactly the kind of problem solving paradigm the business world highly values. It closely resembles the way engineers look at the world; and very importantly it can be applied to more than just "technical" problem solving. It is a disciplined way of thinking and questioning which gifted and talented students may profit by.

For some time now, the technology education curricula, both nationally and internationally, has been capitalizing on the way engineers solve problems. Engineering is a composite profession, blending science, math, technology, and invention with the economic, social, environmental, legal, and regulatory aspects of a problem....to reach a mediated solution. In a STEM directed educational experience, much like the engineering world, all problem solving is open-ended, driven by the questions one asks at the outset of the problem-solving event.

Two main thrusts define the quality of an industrial problem's solution:

- The speed by which the solution is achieved...so as to maintain competitive position in the marketplace; and,
- The robustness of the solution...its ability to most completely solve the problem.

Both are intimately related to the quality of the questions asked at the outset. High quality questions lead to high quality solutions. High quality questions recognize and appreciate the interrelatedness of the dimensions of the problem. Keep in mind that speed of solution alone is not ideal. A great solution is one that has taken the time to thoroughly evaluate the impact a solution will have on customers, society, the environment and other sectors of civilization, and has developed a way to minimize those impacts.

One can think of the science, math, technology, and invention dimensions as "hard", and the economic, social, environmental, legal, and regulatory aspects or dimensions as "soft". Hard dimensions are interpreted as quantitative in form, and soft dimensions as more qualitative in form.

In the modern industrial world, engineers deal routinely with resolving the hard and soft aspects of problem solving---often accomplishing this by assembling inter-disciplinary corporate project teams to examine key topical areas and their interrelated concerns. Very few engineers (and other workers and professionals as well) work in solitude in the corporate workplace, even those involved in research and development functions. The coin of the realm in modern corporations is team-based project management, getting new products out the door as efficiently as possible, and doing so in a way that makes those products function harmoniously across the fabric of civilization....i.e. the high quality, or complete solution.

A Note to G&T Teachers

Liken the STEM process and its quest to identify and assess problems from multi-disciplinary and multi-dimensional aspects to how in the environmental world one crafts an environmental impact statement. Such a

statement attempts to examine the inter-connectedness of a proposed project on the environment into which it is proposed to be placed. All major projects must undergo such an impact analysis. It is a great way to show how STEM-like thinking is applied in the real world. By the way, environmental impact statements date back to the early 70s.

A key challenge to STEM-based education will be to arrange the academic day in such a way that student team problem solving groups have enough time allocated to address, and question the multi-dimensional aspects of a problem; and teachers who can appreciate and lead this kind of problem solving in a mentorship or Socratic way. This can lead administrators to see the academic day as more than simply an eight slice pizza-pie day of 40 minute blasts of information. Perhaps the new school day will be a mixture of block scheduling or perhaps even studio-style design experiences where teachers of different disciplines jointly lead student design teams. Both students and teachers in this environment will need to be educated differently.

The educational model we use today, an atomized approach, mimicked the early industrial model where assembly lines ruled the corporate factory; and specialization and discrete tasks for workers to perform over and over again were the norm. In the digital age or information revolution, we call upon a worker's higher order skills to be applied. A different kind of thinking, reasoning, analytical worker is needed to help a company survive the globally competitive crucible. School is now being called upon once more to prepare workers for a new modern world. It is time to seriously re-consider the academic day in ways that promote STEM-like activities.

Putting STEM in Perspective

Gifted and talented students should welcome this new style of teaching, embracing the opportunity to mix together all that information from their many subjects; and in doing so be able to envision a more comprehensive appreciation for how new ideas get converted into new products; as well as the process for making real-world decisions is revealed. Once a STEM-like approach to making decisions is understood and mastered, it works on any kind of problem. It becomes a life-long skill, and powerful way to evaluate and control one's life and destiny. Encourage your gifted students to think about the world like the popular mantra of the environmental movement...everything is connected to everything else. In a vibrant culture like ours impacts on one end of the cultural fabric cause wrinkles in another part of it. The key is all about asking very good questions and answering these questions in a comprehensive manner.

Let's take an example close to home for your talented students. Some day they will go off to college and this causes some very big impacts on each student's family. Mom and dad have to think very carefully about this and so does your gifted student, whom we shall call Danny. Look at how this decision causes questions to be asked, and the interdependence of those questions, and their impact on Danny's family:

How much will it cost to send Danny to college?

Do we know what interests Danny has because it can affect how much it will cost to go to medical school, versus engineering school, or perhaps business school?

Can he obtain the kind of quality education at home in a state school or will he need to go away to college?

Is Danny going to benefit more from being on his own away from home?

If Danny goes to college, how does it affect his younger sisters' ability to attend college, and family's ability to pay for multiple college educations?

Will Danny have to work to help generate the money for college; and how will it impact his high school and college experience?

Will his social life be impacted negatively?

Since Danny is taking G&T and advanced placement courses now, will this help him get the college he wants?

Are there other courses and electives that Danny should take?

How do college savings for Danny and his sisters impact the whole family and its ability to enjoy vacations, trips, and other experiences, including where it can afford to live?

Does mom and dad's current income provide for levels of savings needed for college educations?

Are both parents' jobs stable enough to allow long-term savings and growth? What happens if one or both lose their jobs?

Danny will be the first member of both parents' families to go to college. Can he handle the high expectations?

How soon should we start looking at and visiting colleges; and do they have special ways to finance Danny's education? What long term impacts does taking loans out on Danny for his education cause down the road after graduation?

Are his college interests in line with making a good salary after he graduates?

These are just some of the many concerns that Danny and his parents must consider. G&T students need to appreciate how the kinds of questions will change with time and the conditions of the economy, the value of a college education, what business looks for in graduates...etc. Life is very dynamic. Asking tough questions is always a good strategy to employ, to gain perspective and to view the complexity of problem solving.

A Note to G&T Teachers

Here is an interesting thing for your gifted students to tackle. Have them compute how much money they are likely to make in the profession they have an interest in, and then compute the lifetime expenses they are likely to incur and how much they can expect to save for their families and future. Encourage them to talk to parents, do some research, make projections and try and account for all the costs in their future lives. Boy are they going to be surprised!!! And don't forget taxes on income and sales.

The Roots of STEM

The roots for the modern day STEM philosophy date back to the late 1800s, when Thomas Edison, a kind of gifted and talented fellow in his own right, was forging his invention factory / industrial R&D concept. It is plainly evident in the small cluster of buildings that formed the central focus of his legendary West Orange Labs. Those historic and important buildings still stand today.

Here in his epicenter of creativity and invention, a one-acre nucleus of buildings formed the heart of Edison's revolutionary enterprise..... an enterprise that would define today's modern industrial model. The small buildings arranged to the side of the main prototyping factory contained certain important specialty expertise and equipment that would be needed to support the multi-disciplined nature of invention. There was a physics/electrical lab, a chemistry lab, a metallurgical shop, a model making shop; and supporting all this were

engineers, scientists, mathematicians, inventors, technologists, machinists, draftsmen, and electricians. Edison knew back then that bringing ideas from concept to market required a multitude of talents and skills, and he had marketing, legal, accounting, economic, and sales expertise on-hand as well.

Today's modern business structure emerges from this integrated approach that Edison formed for the solving of problems, and the launching of new products. The world's greatest companies today have R&D labs like Edison did, fully understanding how R&D project management crucially drives the process of new product commercialization.

It is interesting to note how that one-acre parcel of buildings at West Orange produced enough new product ideas to keep the surrounding fourteen acres of massive buildings around it busy turning out new products. At one time, the great inventor had 30 companies working under the imprimatur of Thomas A. Edison Industries. This is the iron core of strength that STEM thinking can produce in the real world. It has been shown to work for 125 years, forming the foundation for the industrial revolution, and today's digital-electronic explosion. STEM is precisely what is needed in our schools and G&T classrooms to show the relevance of the school-to-work progression.

The STEM of yesteryear has certainly evolved, and will continue to do so as mankind advances. Back in Edison's time, most folks were satisfied that new products were time-saving, understandable, and affordable. As our civilization progressed, we developed new concerns like environmental stewardship, product safety, and regulatory impacts that began to re-shape the way we saw the Edisonian model of progress; and this made new product development ever more complex, multi-dimensional, and inter-disciplinary....and all of this is good for a society's growth....but make no mistake, STEM's taproot lies at the heart of the legendary West Orange Labs, and the seminal idea of perpetuating the industrial revolution as a codified process....a process that revolutionized the cottage industry of invention into a commercial powerhouse. It is Edison's greatest invention.

Today, the total money spent on all national R&D in all sectors is about \$370 billion. That is bigger than the largest US oil companies, and also the entire electric utility industry, probably getting close to giants in revenue like Walmart and the automakers. Obviously this style of STEM thinking has produced and continues to produce great success and wealth.

A Note to G&T Teachers

Turn your gifted students on to Thomas Edison. He was an amazing man who pound-for-pound gave the world more wealth than any other human who ever lived. His ideas about education and creativity are so very relevant to our world. Time magazine in July 2010 dedicated the cover and inside to the relevance of this man. Check him out!

Edison's Invention Process

It is possible to summarize the Edison invention process as discrete steps shown below. Keep in mind that invention is an iterative process, often characterized by false starts, wrong assumptions, and failure. If things don't work out the first time through (and most things don't), the inventor returns to the beginning to re-think the initial assumptions that originally kicked-off the invention process. Remember, it took Edison over 10,000 experiments to master his legendary nickel-iron storage battery, and this enabled him to offer a good product to industry.

It's crucial gifted students not become frustrated when solutions do not "plop out neat and clean". The world and problem solving within it are messy, iterative, and not as clean as a "given this-find that" textbook example. For many decades, school has simplified problem solving. Now in a world of increasing complexity, it's time to show more of that complexity so G&T students get comfortable with that complex world.

A Note to G&T Teachers

Take some time to have your G&T students research what project managers do. This highly-paid and respected position exemplifies how STEM gets put into action in the corporate world. You do not have to be an engineer to be a project manager, as many professionals are not, but they certainly think, act, plan, and implement like an engineer. In fact, most teachers use project management in their classrooms!!!

Take a look at Edison's invention process to gain perspective on how the problem solving process can work.

1) Identify a Problem Worth Solving

Inventors invent to make money so they can invent more things. Capitalism and the insatiable desire to create new things are the two most important drivers of the inventive mind. This cannot happen unless good problems are chosen, problems for which a marketplace exists to pay for the solution or new product. This is crucial. Innovation is invention (STEM) plus marketability. Invention for invention sake may be fun, but it is not a good business model for a hungry inventor.

2) Evaluate the Economics of the Problem

Evaluate the marketability of the solved problem. Who would buy it and why? Where are the possible markets for it? How much should it cost to make it affordable to buyers? How would the new product be marketed...through what means? Would this product also have other applications? Invention is already a high risk sport. Understand the market! If an invention fails, it is almost invariably because of a poor understanding of the market potential of the invention.

Some Interesting Websites to Visit

<http://www.nps.gov/edis/home.htm> (Edison National Historic Site - in West Orange, New Jersey)

<http://www.charlesedisonfund.org/> (The Charles Edison Fund)

<http://www.thomasedison.org/> (The Edison Innovation Foundation)

<http://www.edisonmuckers.org> (The Edison Innovation Foundation)

About the Author

Harry T. Roman is a retired engineer, teacher, author, and inventor. He holds 12 U.S. Patents, and has written and published over 500 papers and articles, including 50 peer reviewed scientific papers. Harry has published 10 books related to his engineering profession; as well as 37 teacher resource books, and 6 educational math card games for the classroom. He is currently an educational advisor and consultant for the Charles Edison Fund / Edison Innovation Foundation.

His feature educational articles for teachers and students appear in Highlights for Children, The Technology Teacher, TechDirections, TIES, and Interface. Every month, approximately 50,000 teachers and educators nationwide read his articles. His books, educational volumes, and games have been published and sold by Kelvin Publishing, Hearlihy / PITSCO, Nasco, PublishAmerica, Professional Publications, Inc., Gifted Education Press, EESC / Bonamy Publishing, the Charles Edison Fund / Edison Innovation Foundation, the International Technology and Engineering Educators Association, the New Jersey Technology Educators Association, and the Institute of Electrical and Electronic Engineers.

In 2005, Harry was inducted into the New Jersey Inventors Hall of Fame as an Inventor of the Year for his work in developing mobile robots for hazardous work environments.

Since 1986, Harry has been involved in the inception, advocacy, and implementation of the technology education curriculum, with its STEM-based, hands-on approach to learning. He writes extensively in this area, and holds the honor of being named a Distinguished New Jersey Technology Educator. For ten years, Harry was an adjunct professor at the New Jersey Institute of Technology where he taught evening graduate courses in engineering and research project management.

He is also a literary writer, with over 800 poems, short stories, and 7 volumes of his creative work published.

Just Published! April 2011

Comprehensive Resource on Planning and Implementing STEM Education Programs for Gifted Students

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By Harry T. Roman

COST = \$20.00 + \$2.00 (10% P&H) = \$22.00

About the Author: Harry Roman is a highly experienced teacher, engineer, technology developer, and inventor. He has extensive experience in teaching gifted students through his courses and teacher workshops for the Charles Edison Fund / Edison Innovation Foundation in West Orange, New Jersey, and through science and technology workshops presented in New Jersey schools. He has published three previous books with Gifted Education Press on Technology Education for Gifted Students, and he has written numerous books and articles on this and related topics with other publishers.

Key Words – STEM Education for Gifted Students; Science, Technology, Engineering and Mathematics; Middle School and High School; Differential Education in STEM; Teacher Training in STEM Education.

About this Book: Harry Roman discusses Planning and Implementing STEM Education Programs for Gifted Students. This is an Essential Book for Parents and Educators which contains many specific suggestions for use by teachers of the gifted in presenting an integrated STEM program. The book covers numerous topics such as the roots of STEM, the study of engineering, importance of math and math activities for the gifted, employee skills, creativity & imagination in the lab, STEM challenge problems, technology education, and applications to the business world.

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