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Introduction

This exciting professional development program for grade K-5 teachers empowers teachers to design approaches and activities to engage students in engineering and thinking skills (tools for engineering) in an interdisciplinary project-based learning environment. The program integrates literacy instruction and the engineering design process to create dynamic, engaging projects that reinforce skills in both areas. It infuses the development of thinking strategies with creative and critical thinking as well as provocative questions and meta-cognitive reflection, skills that are part of the engineering process. By using children's literature as the inspiration for design projects, this approach endeavors to enhance reading comprehension, and to make ties to language arts skills through writing and presentation of projects. This approach defines engineering as "designing useful products & processes for society using all disciplines, but mainly science & mathematics".

Kids also must learn to think across disciplines, since that is the source of most new breakthroughs. It is interdisciplinary combinations—design and technology, mathematics and art—"that produce YouTube and Google," says Thomas Friedman, the best-selling author of *The World Is Flat*. If students are to function successfully in a highly technical society, then they must be equipped with lifelong learning and thinking skills necessary to acquire and process information in an ever-changing world

The core idea of our approach is that engineering need not "stand alone" in the curriculum, but can and should work with existing curricular elements -- in particular literature and expository texts. We envision a curriculum in which students explore, engage with and respond to texts through engineering design projects. Students will focus on identifying needs that the characters have, identifying multiple possible solutions, and exploring and refining those solutions through prototyping and revision. For example, kindergarteners might respond to a common fairy tale by designing a house for one of the little pigs (or perhaps a means of blowing down a house for the wolf!); fifth graders might respond to the book *Island of the Blue Dolphins* by identifying needs and alternate solutions for Karana, the marooned main character of the novel.

Background: Our goal is to research how, in a systematic way, to create interdisciplinary project learning experiences using school literature and expository texts as a basis for engineering projects, and engineering projects as a way to reinforce literacy learning. Many of you have probably done projects around literature and other subjects, but we hope to develop a systematic approach that provides your student with the ability to find and address engineering design challenges in the stories they are reading.   This translates to a project-based learning environment where the students are engaged in finding challenges, designing potential solutions and reporting on them as part of teams. We are offering professional development (PD) to introduce engineering design & the integrated engineering and literacy approach to educators through hands-on projects, discussion, and evaluation of student work.   We hope to

evaluate this concept in urban, rural and suburban school districts and establish a sustainability model that includes on-line collaboration by teachers and incorporating this PD as a supplemental curriculum in teacher colleges.

Why use Literature?

1. Literacy is an integral part of all existing school curricula.

2. Stories have the potential to present situations that can challenge children's imaginations.

3. Some stories can serve to encourage students to begin to generate design proposals and connect to science and math (STEM).

4. Literature is an area of the curriculum that all teachers are familiar with and thus the design process can start from a position of strength within the classroom.

We believe some of the benefits are:

• Showing that all subjects can be interconnected in meaningful ways.

• Doing a whole project versus learning about just a small section.

• Showing that it's OK to make mistakes, in fact it's a way of learning.

• Teachers can integrate this in their existing work and begin to create pockets of interdisciplinary learning.

• Students who experience design-oriented activities in all disciplines will be more likely to develop a deeper understanding of the creative process itself, independent of disciplines.

This program explicitly addresses innovation and entrepreneurship in a number of ways. First, there is a clear focus on finding, understanding, and defining problems or needs. Students must identify with characters in literature, and decide what opportunities might exist to help those characters. As such, the program is heavily focused on the entrepreneurial skill of opportunity identification and assessment. Second, because the program is heavily oriented toward the kinds of thinking skills that the engineering design process requires, it includes substantial emphasis on the kinds of thinking that lead to innovation. Third, teachers and students use divergent and convergent thinking processes and techniques (e.g., brainstorming, criteria-based idea selection) as they develop their ideas for how to respond to the needs of characters in literature. Finally, the design of the professional development workshop is meant to lead to curricular innovation. While participants will be introduced to various techniques and the

engineering framework, they will be responsible for designing their own projects, and will utilize innovation-oriented design techniques to do so.

Essential Questions

1. How will I be the "coach on the side" versus the "Sage on the Stage"?

2. How can I encourage creative learning?

3. What makes this a non-scripted engaged learning experience for the students?

4. How can the engineering activity enhance literacy and vice-versa?

5. How do I integrate science and mathematics into all of this?

6. How will I identify the engineering or beginnings of engineering in what my students are doing/saying?

Why are we doing this?

- We need to move from a culture of memorization to a culture of thinking, creating and understanding.

- Our students will change careers many times and need to learn how to be life-long learners and questioners.

- The students should see the fun & excitement of learning, which includes engineering design, mathematics and science.

- Engineering is increasingly being included among science & technology standards and has been part of the Massachusetts science framework since 2001.

- Design thinking provides a connector for interdisciplinary learning to support the engagement of the students.

Objectives for Teachers

During the professional development, we want to help you…

- Develop a sense of what engineering is

- Develop a sense of what the beginnings of engineering looks like in students, and

- Understand the practicalities of what an integrated engineering & literacy unit will look like in the classroom.

During the professional development we will…

- Discuss the nature of engineering and the engineering design process, both as it is defined in the Massachusetts Curriculum Framework & by other sources.

- Explore creative practices for engaging students in the design process.

- Design & build solutions to engineering design challenges inspired by children's literature.

- Create a plan for integrating engineering into the classroom in a way that is exciting and fun for children to learn.

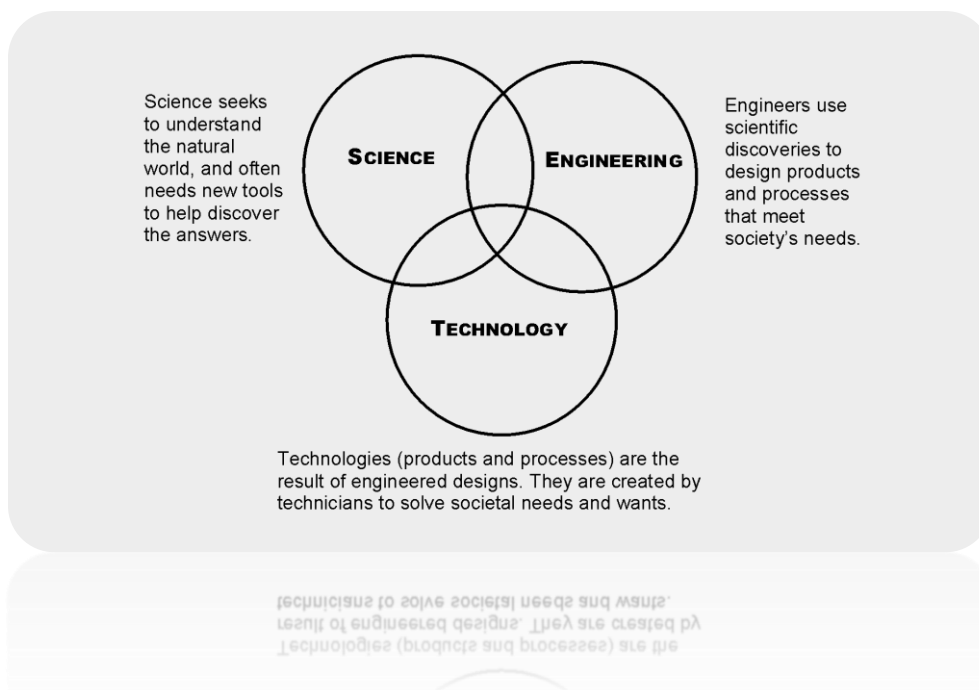- Design lessons that are interdisciplinary and utilize the engineering design process.

What is Engineering?
- **Defining Engineering**
- **Engineering Design Process Models**
- **About the Engineering Design Process**

Defining Engineering

Engineering is about designing useful products and processes for society using all disciplines, but mainly science and mathematics.

- Engineers design products and processes to fill a need or solve a problem

- Engineers use knowledge from a variety of disciplines (primarily science & math)

Science seeks to understand the natural world, and often needs new tools to help discover the answers.

SCIENCE

ENGINEERING

Engineers use scientific discoveries to design products and processes that meet society's needs.

TECHNOLOGY

Technologies (products and processes) are the result of engineered designs. They are created by technicians to solve societal needs and wants.

- Scientists seek to understand nature – they develop theories and seek truth; in science, theories compete to get to one true answer.

- Engineers identify needs and problems and create a solution – there can be multiple solutions, with no single right answer.

- Using science (and other knowledge), engineers design technology .

- Technicians create the technology that engineers, scientists, and society use.

Definitions:

- Engineers design useful products & processes for society using all disciplines but mainly science and mathematics. (composite)
- Science is about explaining patterns in the universe. (composite)
- Mathematics is the language to manage/explain a design & account for the patterns in nature. (composite)
- Entrepreneurship is the practice of starting new organizations or revitalizing mature organizations, particularly new businesses generally in response to identified opportunities. The behavior of the entrepreneur reflects a kind of person willing to put his or her career and financial security on the line and take risks in the name of an idea, spending much time as well as capital on an uncertain venture. (Wikipedia)   Creating value where there was none!
- Artist: a person whose creative work shows sensitivity and imagination. A follower of a pursuit in which skill comes by study or practice - the opposite of a theorist. People who use imagination, talent, or skill to create works that may be judged to have an aesthetic value. (Wikipedia)
- Technologies (products and processes) are the result of engineered designs. They are created by technicians to solve societal needs and wants. (Science Framework)

6 Hats, Ed DeBono

In Vygotsky's work, a mediator is something that stands as an intermediary between an environmental stimulus and an individual reposed to that stimulus. The teacher certainly can encourage these types of thinking. The concept of the 6 hats can be a resource for the teacher.

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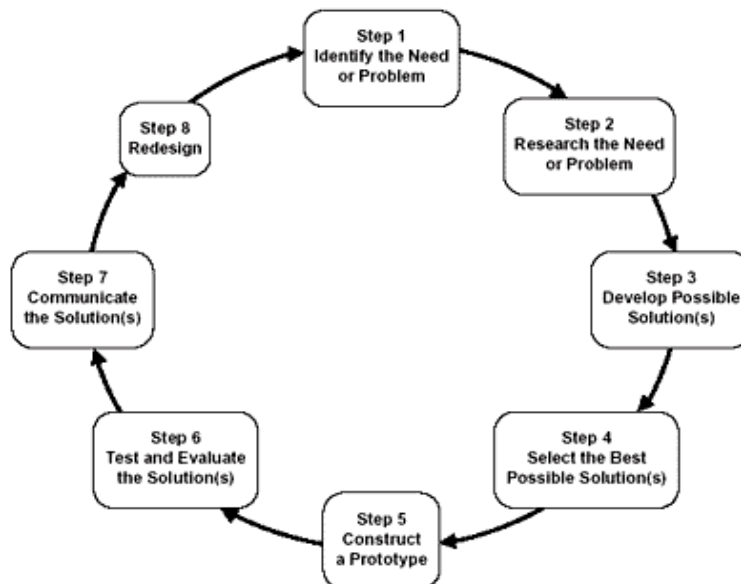
© www.mindmaps.moonfruit.com
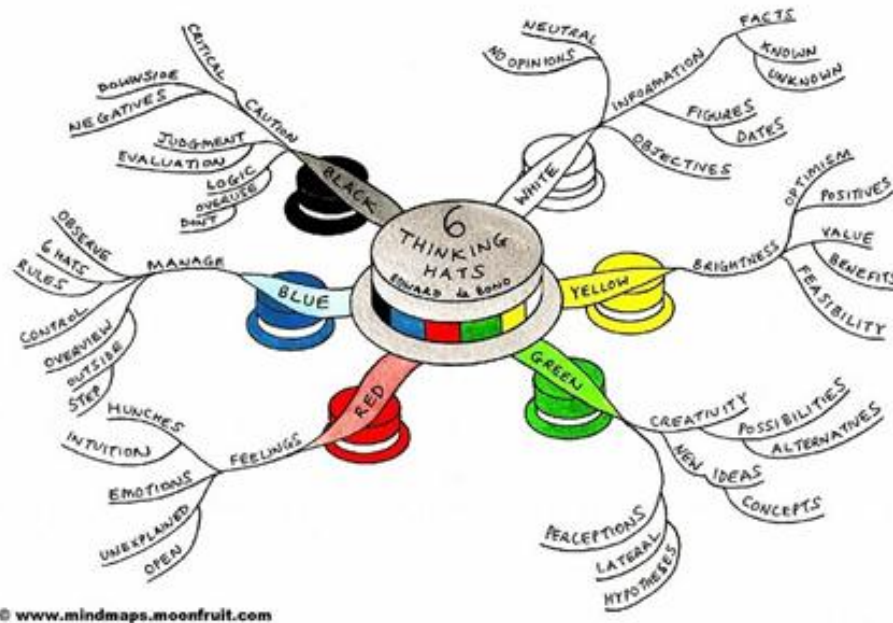
1/29/2012   Ponds to Particles_1st week
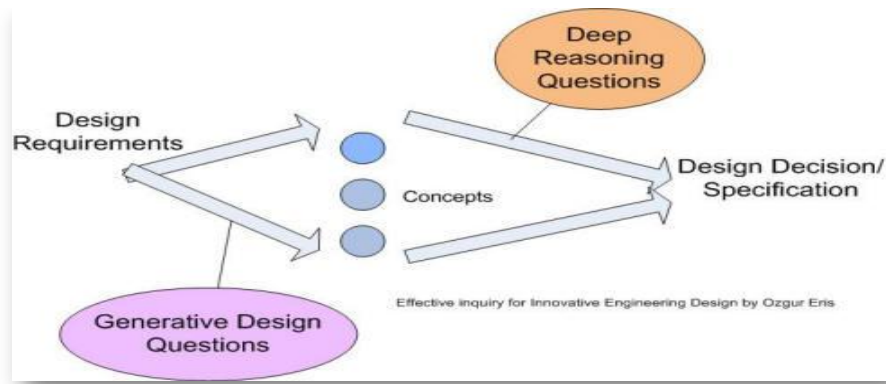
Engineering Design Process Models

We are convinced that engagement in the practices of engineering design is as much a part of learning science as engagement in the practices of science
 ...Science common core ... Preliminary draft July, 2011

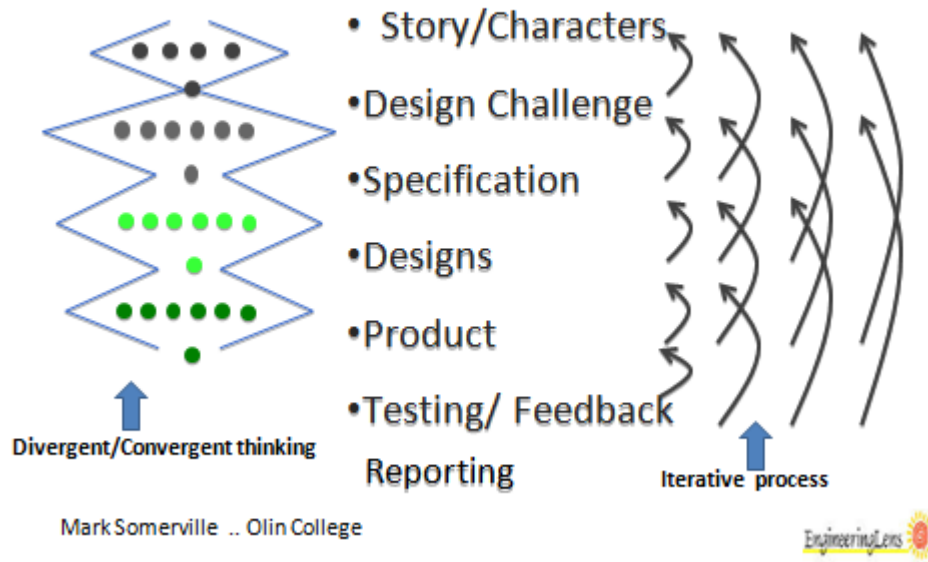Source: Mass   Science Framework

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Effective inquiry for Innovative Engineering Design by Ozgur Eris

Engineering Design is a question-driven process! … Ozgur Eris

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Engineering from Product Reviews … Engineering is all around us.

Engineering Analysis of Products

- Engineering is all around us.
- Let's look at some products to see some examples

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How was science or math used in describing or defining the design?	Goal: Show students that science and math are used in creating products.
Math: to have a sharpen point, we need to understand the math of a cone. **Science** can apply to the chemistry of the paint of the pencil, the forming of the metal hold the eraser, creating and producing the writing material (carbon, graphite)	

Class project

Action Items:

Look at the items in your box. How would you evaluate them?
What categories would you create to compare and contrast them?

- Tell the class what you liked and didn't like about each object.
- Also consider value and innovation.
- Discuss how science and math are used to design them.

Create a table to describe and pick the one the group likes

Categories	Item 1	Item 2	Item 3	

Possible Design categories (choose no more than 5)

Function, Style, Esthetics (look & feel), Cost, Quality, Manufacturability, Safety, Environment, Features, etc ...

Decision Matrix

Requirement	Weight		
environment			
simple			
low cost			
Total=			

requirements

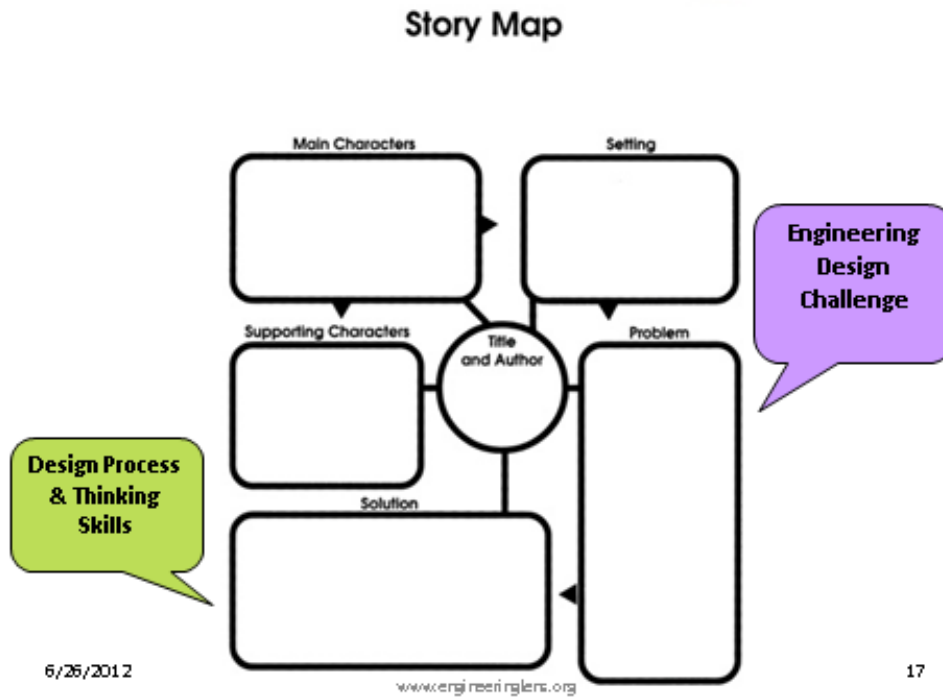Engineering Design Process Elements:

Elements of the Engineering Design process:			
Priming	**Generative**	**Convergent**	**Defining**
Story Mapping	Brain Writing	Discussion of Pro/Con	Gallery Sketches
Needs	Morphological Analysis	Shaping	Modeling/Building
Problem Framing	Shaping	Requirements	Posters
Values	Brain Storming	Decision Matrix	Presentation
Constraint Science	Scamper…checklist of idea-spurring questions		Mathematics
Others			

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Starting a Story:

Story Map

Main Characters

Setting

Engineering Design Challenge

Supporting Characters

Title and Author

Problem

Design Process & Thinking Skills

Solution

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Framing the problem:

Starting with questions

If the design challenges don't jump out to you or your class, a good way to start is by using the 5 W's (Who, When, Where, What, Why) plus How in question format to begin. As an example you can ask yourself the following questions:

- Based on your listening to the characters, what product could they use to make them better?, wiser? …
- What problems do the characters have for which we can develop a product or process to help them?
- What item is mentioned in the story that we can redesign to improve?
- What item that focuses around science (habitat, weather, energy, materials) can we design to change or enhance the story?
- What science from the curriculum can we connect to our story?
- What events are happening that we can focus on?

Students need questions to turn on their intellectual engines and they need to generate questions from our questions to get their thinking to go somewhere. Thinking is of no use unless it goes somewhere, and again, the questions we ask determine where our thinking goes.

What makes a good design challenge?

Fun.
Solves a real problem.
Tied to science and math.
Can be done with paper or using simple materials that the children are familiar with.
Can create many learning extensions from it.
Can add your requirements to change the location or theme to suit your learning needs.

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Finding ideas … Divergent Thinking

Brainstorming ... A systematic effort and disciplined practice to produce ideas in a group. Create an un-inhibiting environment that would encourage imaginative ideas and thoughts. The usual method is to have a small group discuss a problem. Ideas are offered by participants one at a time. One member records ideas and suggestions on a chart or white board. All withhold judgment. After the brainstorming session, the various ideas and suggestions are reviewed and evaluated and the group agrees on a final resolution.
 Rule 1: Postpone and withhold your judgment of ideas
Rule 2: Encourage wild and exaggerated ideas
Rule 3: Quantity counts at this stage, not quality
**Rule 4: Build on the ideas put forward by others**
Rule 5: Every person and every idea has equal worth

Problems with Brainstorming
Certain elements within the Brainstorming process lead to difficulties while implementing. Because it is very open, some people feel intimidated by others to speak out freely. Also some people tend to take control of the process. Brain-writing helps eliminate some of these concerns by having each person create the ideas on their own and other people read them as notes, which are not on public display.
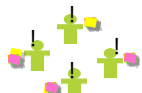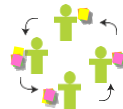
Generate Possible Solutions using Brain-writing

Starting with 4-5 generative framings…
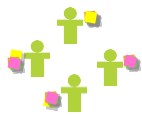
Each team member generates
3-4 ideas on their own.

Pass ONE of your ideas to your right.

Read your neighbor's idea, and generate
an idea that is somehow inspired by it.

One idea per card
or sticky note!!

Repeat until time is up.

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Shaping ideas:

Is a technique to group ideas into three categories (ordinary, innovative, magical) and then use the results to move the ordinary and magical ideas towards the innovative. It's a technique to both sort and help create new ideas.

Shaping Ideas

Why generate crazy ideas?

So you can shape them into innovative ideas!

Leaves falling on the lawn...
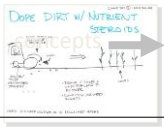
Use a leaf blower

Trees that pick up

magic

I   !?   !!!??

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Convergent thinking … Narrowing the # of ideas and making a selection

Discussion: During the design process or problem solving we need to apply convergent thinking to narrow our options to a selection. When we have many options and are not comparing any to an existing one, the best option is to create a decision matrix where we establish a set of judgment criteria down the Y axis and weight each to its importance to judge our possibilities.

Requirement	Weight	VISOR SNORKEL	DOPE DIRT W/ NUTRIENT STEROIDS
environment			
simple			
low cost			
Total=			

requirements

Requirements:
- Formalize what the design has to accomplish
- Safety, function, interaction, character
- "The design should…"
- Specify the need, not the solution:
  - Good: "provide space for a family of six to eat together"
  - Bad: "include a dining table in the middle of the room."
- Science Constraints are requirements you impose on your students

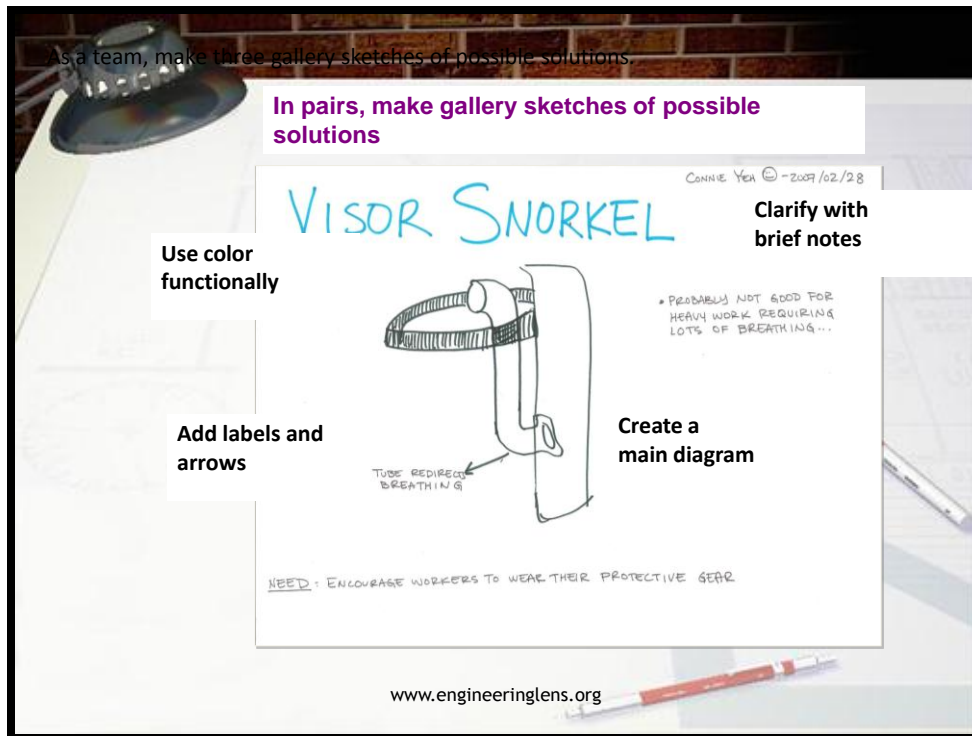**Initial List of Requirements**

The design should:

Safety
Not have pinch points
Not have sharp features exposed to users
Not be applied to people

Function
Not over drive or under drive nails
Allow for accurate nail placement
Be durable
Drive one nail quickly
Drive many nails in a session
Drive most roofing nails and similar nails, such as for barrier material
…

Interaction
Be accessible to color blind people
Be easy to position
Allow a person to use it for a long time without getting fatigued
Be ergonomic
Be transportable
Require only one person to operate
Be easy to maintain
Allow a person to discover how to use it easily
…

Character
Provide a feeling of satisfaction when operated
Appear rugged and durable
Have a modern look that fits the other equipment on the site

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Example:

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Sketching

Building and Testing

As we build from our sketches, new ideas might come into our minds. It's OK to follow those thoughts and iterate the process. Our testing method is critical in that it is how we insure that our original idea is proven or disproven. We should develop the basic test method during the design phase.

Presenting your ideas to others

- ✓ How did we approach this design challenge?
- ✓ What did we know?
- ✓ What did we learn from our research and other projects?
- ✓ What would we do differently the next time and why?

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Thinking Skills

Thinking Skills Environment

Rev	Description	Approval	Date
3			052909

Creativity improves pupils' self-esteem, motivation and achievement

Creative Thinking
- Brain storming
- Divergent thinking
- Exploring, generating ideas
- Stimulate curiosity
- Innovation & entrepreneurship

Questions
- Logical Sequential
- Open ended
- Listening is the first step in good questioning
- Provocative
- Engage
- Encourage higher order thinking

Critical Thinking
- Analyzing the past
- What evidence?
- What is the authors purpose?
- Convergent thinking
- Skepticism is a virtue

Reasoning Skills   Information Processing

Learning environment
- Set Values
- Focus on vocabulary
- Make thinking visible
- Don't look to blame
- Incremental learning
- Learning from mistakes
- Learning is collaborative
- Excitement/enthusiasm leads to fun & play
- Wait 30 sec before answering
- Let students know how to succeed (rubrics)

Meta-cognitive reflection
- What do I want to understand?
- What have I learned?
- What do I still need to learn?
- Provide feedback for reflection
- Regulate ones behavior

Create your thinking strategies:
- Look to make your approach more efficient.
- Look at issues from a system view with inputs, outputs, processes and feedback.
- Think of strategies in "gathering, organizing, analyzing and making conclusions.
- Break problems into small chunks and study them well.
- Begin with the things that are simplest to understand and move to the more complex.
- Never to accept anything as true that you do not clearly know.
- Be complete in both your work and reviews that nothing is omitted.
  Descartes, Discourse on Methods

Creating an environment that fosters and values thinking
When we honor kids' thinking, they learn that their thinking matters. Students and teachers feel free to take risks as learners when they know their thoughts, ideas and opinions will be treated respectfully by others. The room arrangement mirrors the focus on learning and thinking with meeting spaces for small groups, a comfortable spot where the large group can gather, and desks or tables in clusters to promote conversation and collaborative work.

Title:		
Doc. #		Rev.
Author	Bill Wolfson	

Design and problem solving process overview:
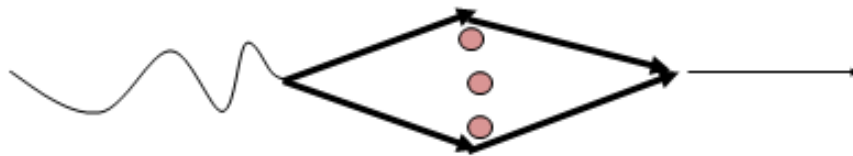
Priming	Generative	Convergent	Defining
History	BrainWriting	Discussion of Pro/Con	Gallery Sketches
Needs	Morphological Analysis	Shaping	Modeling/Building
Problem Framing	Shaping	Requirements	Posters
Values	Brain Storming	Decision Matrix	Presentation

Listen to the needs and values of the customers

- Generate raw ideas for a given challenge
- Select an idea that is particularly interesting
- Identify the requirements for that concept
- Come up with multiple solutions that meet the requirements
- Select a solution, based on the requirements

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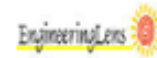
The Missing Link: Engineering Design Process and Thinking Skills

Recommended titles to use for design challenges

Introduction:

The following literature selections are organized into four categories: fairy and ethnic tales, picture books, and fiction chapter books. Each selection includes appropriate grade level range, story summary, and possible design challenges. Some selections also include extensions.

"Engineering design challenges" are created by actionable items in the story and lead to inquiry based team projects that have a design theme. As an example, in the story "Island of the Blue Dolphins", the village leaves canoes on the side of a hill for escaping a potential attack. The heroine in the story has a difficult time getting one of them down the hill and into the water. A "design challenge" for the students could be to design a system to make it easier for her to lower the canoe.

The students can pick the character they are working for in the story to create a design challenge. As an example they might want to work for the wolf in the 3-pigs to find a way to catch the pigs.

Reference Documents
Example of a lesson plan outline (PDF)
Story flow map (PDF)
Design/Problem solving process (PDF)

Fairy and ethic tales:

"3-Pigs"	"Goldie Locks"
"One Grain of Rice" by Demi (Math fairy tale)	Hansel and Gretel

Picture Books:

"The Carrot Seed" by Ruth Krauss	"Owl Moon" by Jane Yolen
"Make Way for Ducklings" by Robert McCloskey	"Snowflake Bentley" by Jacquelin Martin
"Who Sank the Boat?" by Pamela Allen	"The mitten" by Jan Brett
"The North Star" by Peter H. Reynolds	"Rose's Garden" by Peter H. Reynolds
"Where the Wild Things Are" by Maurice Sendak	"A visitor for bear" by Bonny Becker
"One Watermelon Seed" by Celia Barker Lottridge (	"Island of the Skog" by Steven Kellogg

Math focus)	
"Ibis: A True Whale Story" by John Himmelman	

Fiction, chapter book:

"Esperanza Rising" … by Pam Munoz Ryan	"Island of Blue dolphins" by Scott O'Neil
"From the Mixed-up Files of Mrs. Frankweiler" by E.L. Konigsburg	"Dear Mr. Henshaw" by Beverly Cleary
"Number the Stars" by Lois Lowry	Charlottes Web by E.B. White
"The Mouse and the Motorcycle" by Beverly Clearly	"Pictures of Hollis Woods" by Patricia Giff
"Tales of a Fourth Grade Nothing" by Judy Bloom	"Brave Irene" by William Steig
"Cricket in Times Square" by George Sheldon	"On the Far Side of the Mountain" by Jean Craighead George
"By the Shores of Silver Lake" Laura Ingalls Wilder	"Blizzard" by Jim Murphy; part of a fifth grade Houghton Mifflin Series , historical fiction
"Snow Treasure" by Marie McSwigan	"Bridge to Terabithia" by Katherine Patterson
"Owls in the Family" by Farley Mowat	"Sir Cumference and the First Round Table" by Cindy Neuschwander

Historical Fiction

The Watsons Go to Birmingham by Christopher Curtis	

Location for titles above, including story summaries, grade levels, and possible design challenges:

http://www.integratingengineering.org/workbook/books_summarys.htm

The Three Pigs

3 pigs

- Discuss the story and the characters.

- What are some of the problems/ design challenges?

- Who do you want to work for?

- What science are you going to use to solve the design challenge?

- How is the team going to approach this design?

Empathy

Book Summary: The 3- Pigs

Fairy tale

Major Characters:
The 3 pigs
The mother Pig
The Wolf
Society

Setting: a Farm location of your choosing

Plot Summary: Mother pig sends her three little pigs off on their own to build their own shelters. Pigs must build their houses strong enough to protect themselves from the wolf, who wants to eat them.

Action Step:
Define the problem or what do you want to design
Create lots of ideas
Converge on the few best ones
Sketch, Build, Test and Report

Story can be seen as a metaphor to the design process; pig tries one approach, which is tested and fails, tries again and is tested and fails, the third time it works.

Possible solutions to problems in *The Three Pigs:*
- How do we design a house to also protect against the weather?
- The pigs move to an earthquake zone, build a house to protect them from earthquakes as well.
- The pigs live in Outer Mongolia. What type of house would they build?
- You work for the wolf, design a suite that can protect the wolf when it goes down the chimney; design a machine that can be used to create air pressure to blow the houses down.
- You live in a community that wants to provide a nice living space for its Pig population. What would you design and why?   What would you do with the wolf population? Can you apply this to humans?
- Build house on hill and use rollers to knock down the wolf.
- Build house on hill in the shape of a triangle so wind can hit only corners.
- Design a house with a strong foundation and internal structure.

Owl Moon

Book Summary: Owl Moon

Picture Book

Major Characters:
The child
The father
The Owl
Other animals
Society

Setting: The woods near the farm lit by a bright moon

Plot Summary: It's a coming of age story of a young child and a first time walk with the father in the cold evening looking for an Owl.

From the Story:
- Our feet crunched over the crisp snow …
- Then he called: Whoo-whoo-who-who-who-whoooooo …
- I could feel the cold, as if someone's icy hand was on my back
- The shadows were the blackest things I had ever seen

Design Challenges:
- Design a shoe that would not make noise on the snow.
- Design an instrument that can make this sound. What causes sound?
- Design a better way to save the heat of your body - a hat with a flap?
- Create a light to see without disturbing the animals.

Reading List

	Book	Comments
1	"Self-theories" by Carol Dweck.	
2	Thinkertoys; by Michael Michalko	A handbook of creative-thinking techniques
3	The Power of Play by David Elkind	About play in learning
4	The Eureka Effect by David Perkins	The art and logic of breakthrough thinking
5	Differentiation in Action by Judith Dodge	Resource to help plan and organize differentiated instruction
6	A Whole New Mind by Daniel Pink	About how using the right brain is important in today's world.
7	Learning to Question to Wonder to Learn by Jamie McKenzie	Sharpening the questioning powers of the young.
8	The Having of Wonderful Ideas by Eleanor Duckworth	Connection between children's thinking and how she interprets Piaget's ideas to them.