Creating an interdisciplinary learning environment between literature, science and math by using engineering and thinking skills as the connectors.

Overview:

The core idea of our approach is that engineering and thinking skills need not "stand alone" in the curriculum, but can and should leverage existing curricular elements -- in particular literature. We envision a supportive curriculum in which students respond to literature through engineering design projects by identifying needs that the characters have, by identifying multiple possible solutions, and by 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 solutions for Karana, the marooned main character of the novel.

Summary Outline of tasks:

1. Create a professional development program(PD)

This will provide a collaborative model for the teachers to learn the following:

- Understanding of what engineers, scientists and mathematicians do. Show that teachers know more about engineering then they think. Teachers interview an engineer.
- How to do creative designs and problem solving. Understanding the design process and use tools like brainstorming, brain-writing, morphological analysis and decision tools.
- How to find design challenges in stories to create an interdisciplinary learning opportunity.
- How thinking skills of questioning, creative and critical thinking, meta-cognitive reflection and strategies are tools of engineering.
- Use of feedback, measurements and assessments are important to the success of a design challenge project. Setting outcome goals to use as the basis for measurements.
- Using inquire base (project based) learning to create 21st century learning experiences.

2. Provide templates and examples

The teachers either by themselves or collaboratively will be creating design challenges from literature so they will need templates and examples to help them succeed. The goal in not to have a fixed set of scripted design challenges but a more fluid one where students can be involved with finding and doing the design challenges. Teachers will be provide with templates and examples of stories and learning aids to support their efforts. The teachers through setting requirements and guiding questions can channel the direction of the design challenge and what discipline they want to emphasize.

3. Assessment of the program/curriculum

The program concept will be evaluated in three major setting; urban, suburban and rural school districts. Both teachers and their students will be assessed to see changes in their use and understanding of STEM subjects and their overall learning improvements.

4. Sustainability Model

The following two outcomes will be created based on the assessed success of the outcome of the program to provide a way of sustaining this program:

1. The PD syllabus will be used as a basic of creative a supplemental curriculum for teacher colleges to use for their program.
2. Interactive web site that will allow teachers to collaborate on developing additional models and sharing them. It will also be a repository of templates and examples for teachers and administrators.

How does the program teach innovation or entrepreneurship?

This program explicitly addresses innovation and entrepreneurship in a number of ways. First, there is an explicit focus on needs finding. Students must identify with characters in literature, and decide what opportunities might exist to help those characters. As such, the program is as 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. In particular, 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 framework, the participants will be responsible for designing their own projects, and will utilize innovation-oriented design techniques to do so.

Goals for the program

The overall indent of this program is to have our children excited about learning and their use of engineering design and thinking skills in their everyday activity. Some of the more specific goals are as follows;

- Teachers understand what engineers do and can use it to motivate their students interests.

- Thinking skills are more visual to both teachers and students.

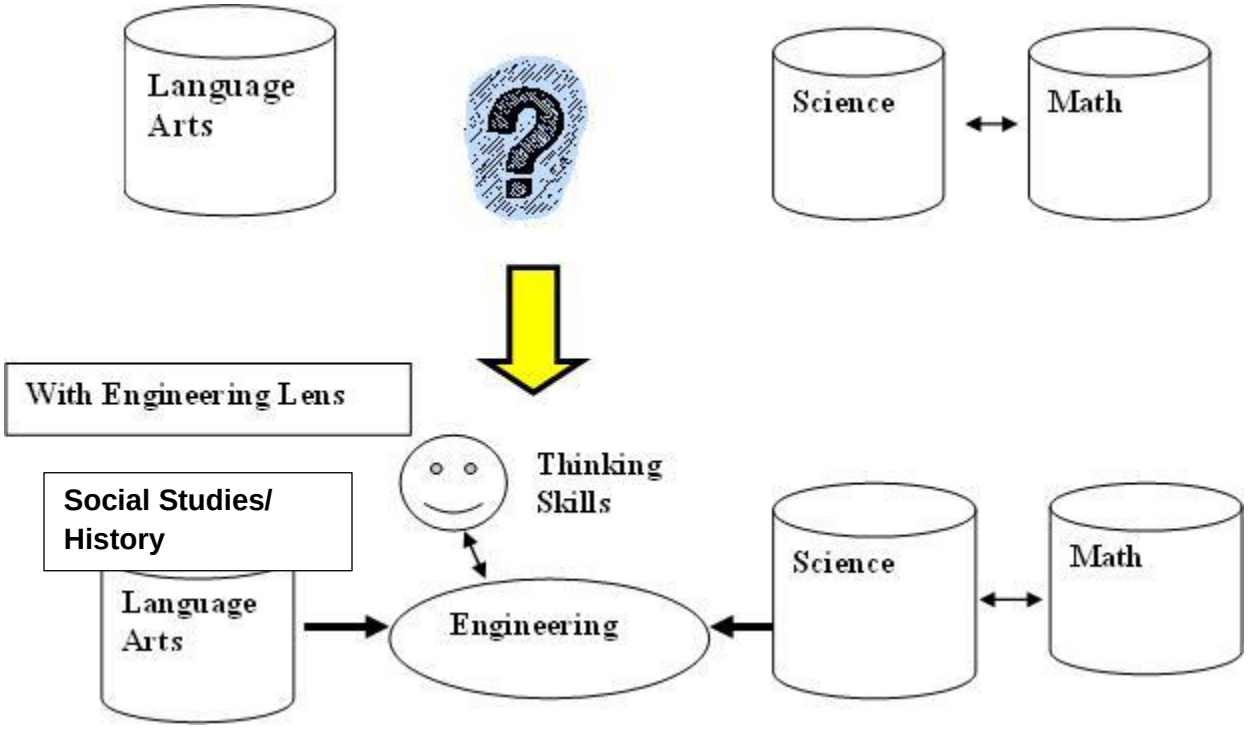
Program Details:

Our program begins with an interdisciplinary approach to learning versus the traditional Silo based learning. The engineering design process and thinking skills are used to connect literature, math, science, engineering and other disciplines in a project based learning environment. We use the following definitions:

Engineering -"Designs useful product and processes for society based on all disciplines but mainly Science" "and Math.

Science: Finding the patterns in nature

Mathematics: The language to describe the patterns and the engineering design



Why interdisciplinary learning:

- Life is interdisciplinary and innovation crosses boundaries.
- Children see the relevance of math and science when done in a project
- Exposes children to 21st century skills of problem solving, collaboration and thinking skills

National Academies of Engineering report, Engineering in K-12 Education (2009), highlights the need to avoid a "silo" approach to engineering by integrating with other subjects

Our approach is to build on the existing knowledge of the teacher:

Many teachers have done bits and piece of this approach. What we bring to the table is a systematic way and a set of tools. Teachers know more about engineering than they think. They use the design process often but have a different vocabulary for it and need to structures tools for it. One of the first steps is to introduce them to engineers through having them interview an engineer and some reading of prominent engineers. This brings a connection between the disciplines that allows dialogue.

Teachers know about thinking skills but need a rich environment that engineering provides to practice and make it more visible for learning. Our approach is to focus an equal time in the early stages of the design process where divergent and convergent processes are modeled.

Finding the Design Challenges in stories

"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 using simple machine concepts. Another example from Goldilocks would be for children to work for the Bears and design a security system to keep Goldilocks out of the house.

Approach:

A teacher normal engages the students with the literature they are reading by asking skillful questions and using meta-cognitive reflection to bring out interesting areas of the story line. What we are adding is an engineering lens on the process to focus those questions from an engineering designer's viewpoint.

It is important to steer the process such that the students feels ownership of what they will do and the learning is not overly scripted. By the teacher setting the requirements for the design challenges, you can set the direction but let the student have some control.

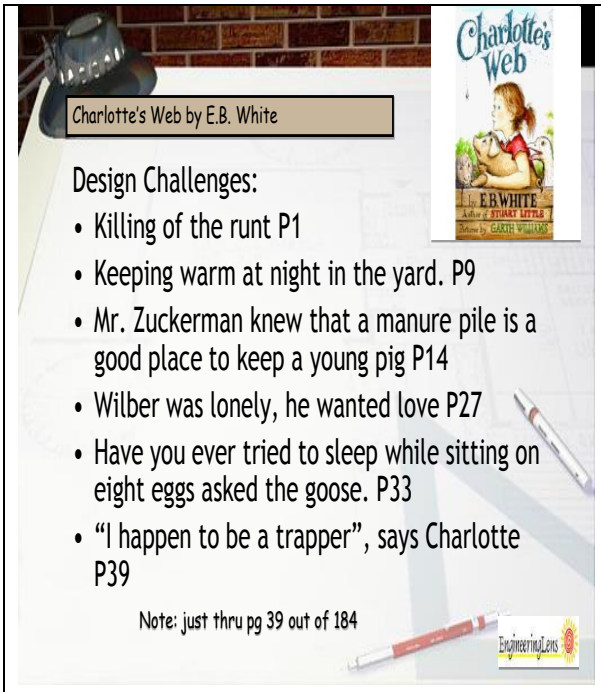
Define an approach for what you want the leaning outcome to be. • Do we want to emphasize the learning of the engineering design process? • Do we want to focus on a science strand within a design process? • Do we want to focus on teaching a thinking skill? Ie creative process
Pick a science strand to connect with, either one that you just studied (used for reinforcement) or one that you are going to study (great Segue).
With an engineer's perspective, use the normal teacher's skills to engage students in the story. … Look at "story map" for ideas, think of engineering key words (create, improve, identify, investigate, etc.). Think of the science you just studied.
Develop design challenges with the students. Have a few in mind to channel the students towards these.
Integrate the engineering design and the science. If you picked the science you just studied, you can ask the students to sort their design challenges around that science. If you are going to focus on the up-coming science lesson, guide your students to view the design challenges around that science. This will give you the teacher, a good segue into the new science lesson.
Use the 8 step design process or modified PreK-2 grade version. Remember that the design process is cyclical in nature and keep cycling back as you have additional knowledge to make better decisions.

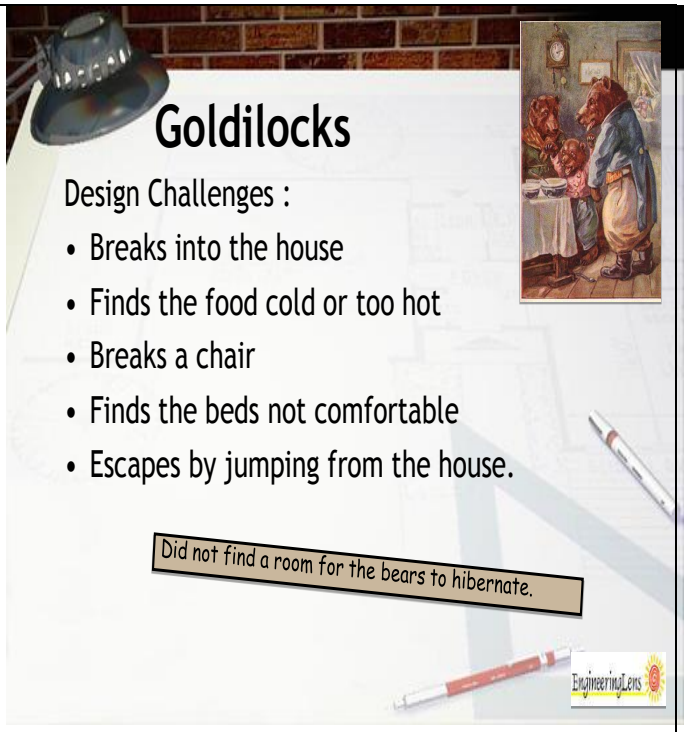
A problem is nothing more than an opportunity in work clothes. A successful business person pays attention to problems, converting the problems into opportunities and deciding which opportunities are worth pursuing. Thinkertoys, Michael Michalko p22

'We are continually faced with a series of great opportunities brilliantly disguised as insoluble problems. John W Gardner

Examples of design challenges in stories:

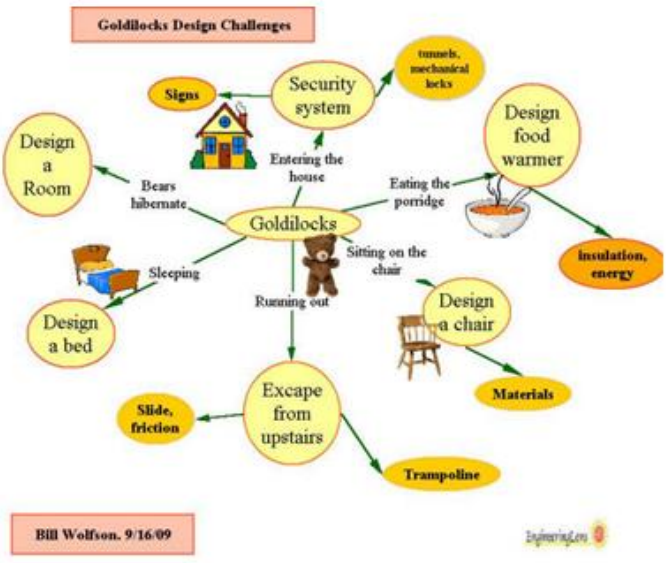
Charlotte's Web by E.B. White	Fairy tale: Goldilocks





From the above, we could pick the design challenge of keeping Wilber warm using the manure pile. The design challenges can be to design a system that extracts the heat from the manure pile and keeps Wilber warm	From goldilocks, we could have a design challenge that the students need to design a box that keeps the food either warm or cool using the science principles of energy transfer (insulation material)

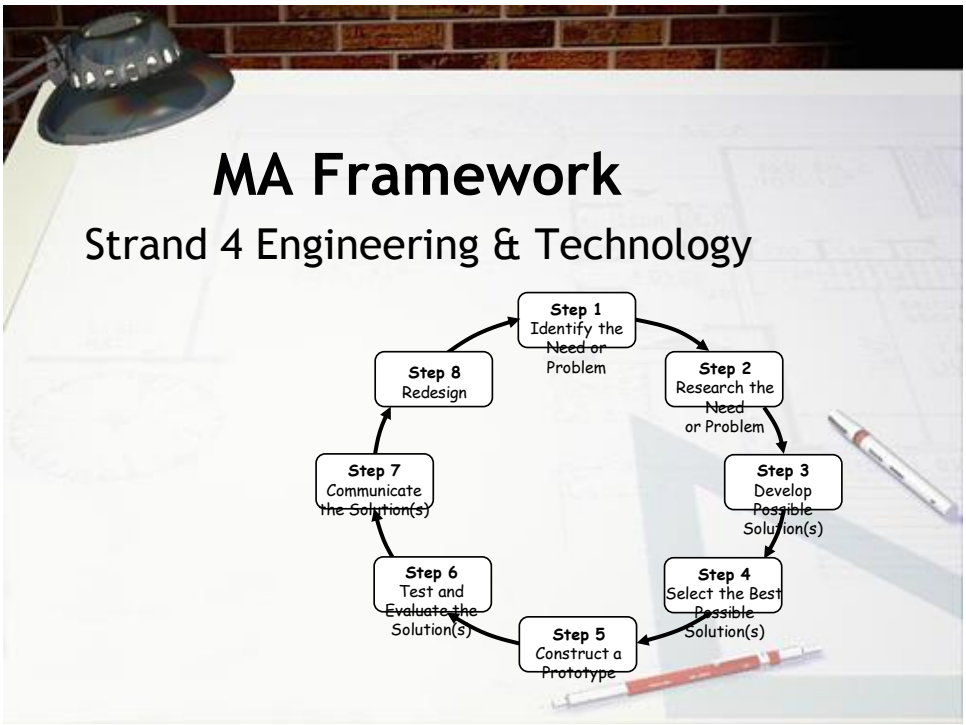
An example of using a mind mapping tool to work with design challenges is as follows:



To do these design challenges we need to understand the design process.

Starting with the design process

We model for the teachers the design process by having them do a design and then analyzing it from the steps they did and the iterative nature of the design. Since our focus is on using the Massachusetts Framework, we discuss the design process in the strand 4 of the science framework



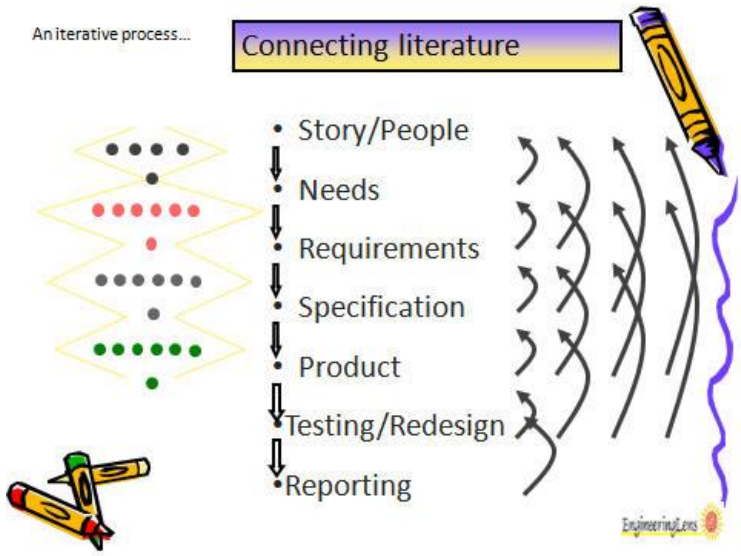
Strand 4 of the Science Framework

But what's missing?

The two major deficiencies in the diagram are that it doesn't represent the following:

- The iterative nature of the process as things are tried, found to need a change and then repeated until it is correct.
- The convergent and divergent process as many ideas are created and analyzed to see which works best for the particular situation.

What we do notice about this process is that it is a learning process and uses thinking skills. In fact, it is a higher order thinking skill. Creative and critical thinking are the main components of the creating and reviewing new ideas, the use of questions to probe what is needed to be done in the design challenge being worked on and meta-cognitive reflection to analyze, evaluate and apply next steps. To represent this design view in another format we can use the following:



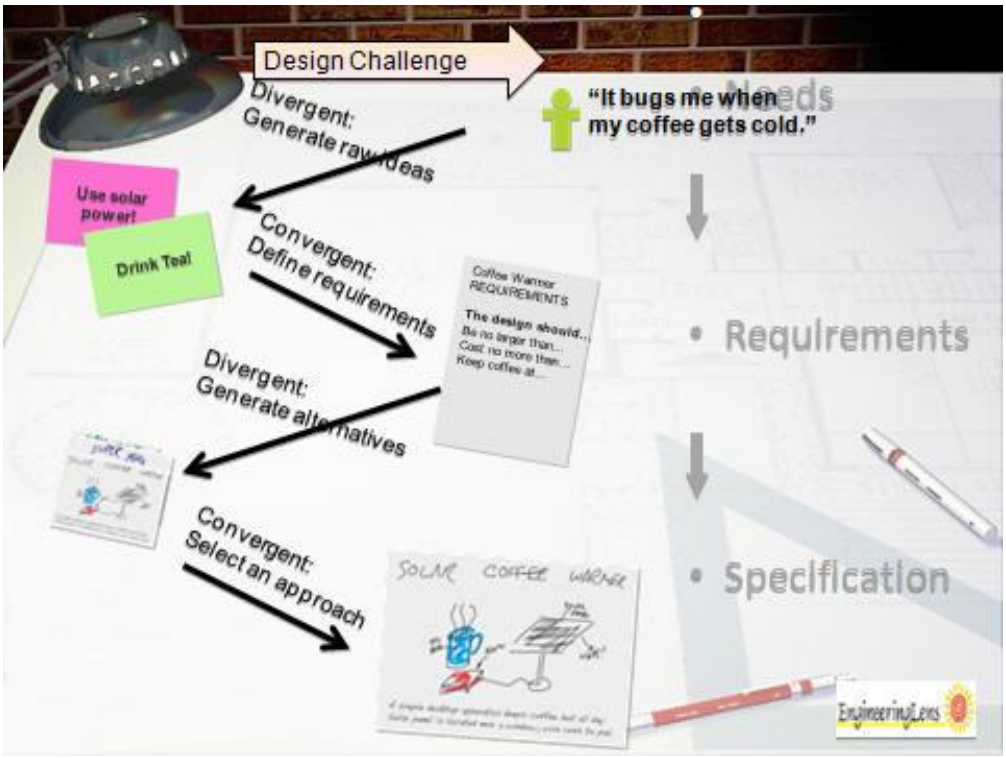
Mark Somerville, Olin College

Design Tools used:

In order to create and analyze many ideas for each of the steps, process can be used to facilitate the task. The following table lists some of the methodologies used. There are many good references such as Thinkertoys, by Michael Michalko.

> *…Design Education encourages your students to see themselves as designers in their own right as they engage in the design process through active observation, critical discussion, the act of making, visual communication and presentation, and critique. The project-based focus of design is a great method of reinforcing teamwork and collaboration. Design also allows for multiple methods of problem solving—a seamless way to differentiate instruction…* **Cooper-Hewitt's Educators' Resource Center**

To see how this works, let's take something that "bugs you", like your coffee does not stay warm in your mug. This could be our design challenge. "Find a way to keep our coffee warm" the slide below give you a feel for the process



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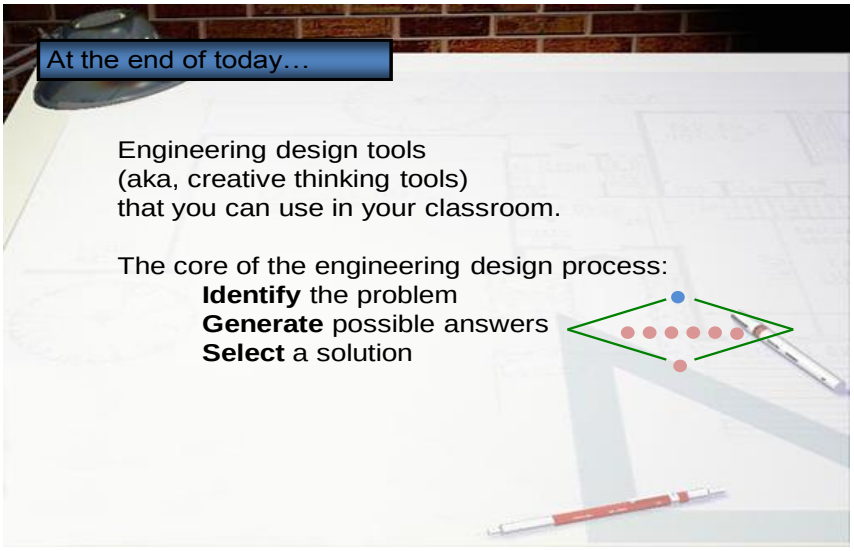


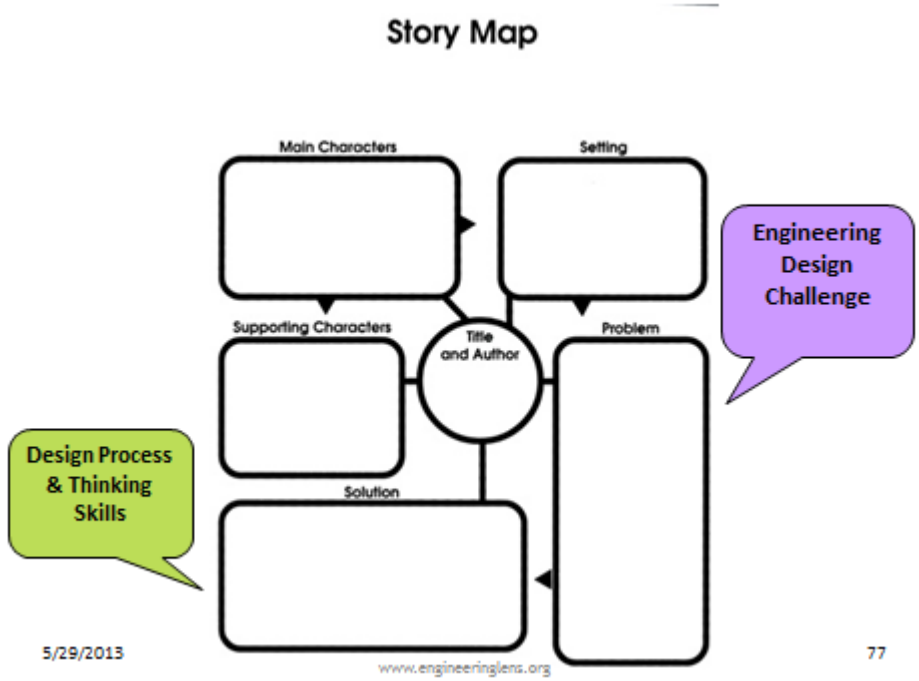
Our goal is to implement this concept in the PreK-5 grades. There will be grade levels where it is not practical to have the children read and respond to a story. Other methods are available to teach this concept to younger children. In the PreK are we have been successful by having the children to be part of creating the dramatic play are and learning such concepts as decision making and brainstorming. The table below gives some examples of things that can be do leading up to a full implementation:

Discussion: How to handle the design process at different grade levels.
Pre-K-grade 1:
Learn vocabulary: design, engineer

Let's do a story:

A good fairy tale to start with is the 3 pigs. This story is rich in many design challenges that you can steer students towards as well as them finding new ones. As an example of what we mean by steering, You can set requirements on the design by imposing different conditions for where and how the design needs to be done. You can set the location of the story to an earth quake fault line to bring in geology or set the location to be Outer Mongolia to design houses like a Yak. You can challenges the students to find a healthy way to solve the issues between the pigs and wolf or design around something that uses "green concepts".

One of the exciting things around doing a design challenge is that you can create extensions to the story to bring in other learning.



Some Design Challenges:

- 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.
- You move to Outer Mongolia, what kind of house would you design and what animal would you be concerned about?
- Students explore properties of light, then apply what they've learned to design and make shadow puppet plays based on 3-Pigs nursery rhyme, to which they invite guests and charge admission. Can also make hand puppets of the 3-pigs characters and study materials and life science.

- Students study about recycling of materials and design a house for the pigs based on what they have learned.
- 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?
- Use zebra grass for the straw. String to build house, use form packing material to build house, compare natural and man-created material.
- Build house on hill and use rollers to knot down wolf
- Design a device that uses boiling water to keep the wolf away from the house.
- Design a trip wire device that uses rocks to fall on the wolf when it gets close to the house.
- Design a fence that will protect all the different houses.
- 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.
- If the students are studying electricity, have them design a switch device that will go off when the wolf steps on it.
- Design a better way for the pigs to travel between the houses.
- Design a device to test the level of force of the wind needed to blow down the house.
- Design a pop-up card that shows the story from the wolfs point of view.

Extensions:

- Invite a parent who works in the construction industry to talk about materials and building a structure
- Visit a construction site with the children.
- Draw pictures of the scenes and do role plays around the story working as engineers
- Keep a journal
- Re-write the story by adding an invention that supports either the wolf or the pigs in the story line .
- Have the pigs design a post card and write home to their mother/father on why where they were and why they build a house. Include pictures of the house, measurement and why they think it is sturdy.
- Compare and contrast the 3 designs. Create a list of items and create a table showing the 3 house designs against the list.
- Have the students describe the safety aspects of building a house
- You are a business person who wants to start a business that provides services to the pig community. What would you do? Design and build furniture for the pigs?, Provide security services?, Build houses? Provide materials/ store?
- Compare prices of building material. Why does some products cost more than others?

Remember, the design challenge starts the design process. We need to design, build and test it and reports on the results. A suggested lesson plan outline could be as follows:

Outline	Description
Introduction	Story selected, Reasons, expected outcomes
Story description	Short description of story and intended age group, Author

Learning Goals	Short review of Content areas, Collaboration, thinking skills, Process … Use to create Rubrics
Prior Knowledge,	Learning the students need to be able to do this story for example; understanding of brainstorming, design process, use of cutting tools, Special skills, etc.
Outcomes *when participating in this activity, students will*	Participate in the Project (Teams, Reports), Becoming a better story teller, Be able to have a dialogue with a character in the story
Teachers Strategy	How are you going to approach this task. Any special things you want to emphasize?
Vocabulary	Any key words that will be emphasized
Design Challenges	List possible challenges found in the story
Requirements	What requirements are you going to set for this book to steer the learning *(Location, Working for which character, Situation, etc.)*
Selected Design challenge to do or other activity based on grade level	You might involve the students in selecting the challenge to do depending on age group. **As an example**, *Younger students might listen to the story and then do a brainstorming activity*
Extensions	What additional content items can be included to enhance the learning process (ie keeping a journal, creating a map, doing a drawing, creating another story)
Framework Standards	What standards are you going to connect the story to? Are you connecting the project to a school standard?
Thinking Skills	Any thinking skills that you want to emphasize. Questioning Skills, Higher order thinking (Analyzing, Synthesizing, etc.), Meta-cognition, creative and critical thinking.
Safety	Any concerns with equipment or tools that will be used
Materials	List of materials that will be needed for the building portion of the project
Rubrics	Using you goals as a guideline, build a rubrics for your project. How can the students be involved? How do you handle with the younger grade levels/
Contact information/ date	

Infuse thinking skills into the process:

An important part of this curriculum is the use of thinking skills as the tools of engineering in creating the interdisciplinary learning environment. We deal with the following elements of thinking skills:

Creative Thinking	Critical Thinking
• Brain storming • Divergent thinking	• Analyzing the past • What evidence?

• Exploring your environment & testing many options • Stimulating curiosity • Innovation & entrepreneurship Creativity improves pupils' self-esteem, motivation and achievement	• What is the author's purpose? • Convergent thinking • Skepticism is a virtue
Questions … Engaging the student • Logical/ Sequential • • Open ended • Listening is the first step in good questioning • Provocative • Engage • · Encourage higher order thinking Questioning	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

Thinking strategies like those discussed be:

To what, then, did Descartes owe his great success as a thinker? He tells us: "It has been my singular good fortune to have very early in life found a methodical way of thinking. In this way I have gradually augmented my knowledge, and raised it little by little to the highest point which the mediocrity of my talents and the brief duration of my life will permit me to reach." The method he found so useful, he tells us, involves four simple precepts:

1. Never to accept anything as true which you do not clearly know to be such; that is, to avoid hasty judgments and prejudice.

2. To divide each difficulty under examination into as many parts as possible, or into as many as necessary for the solution of the problem.

3. To begin with the things that are simplest and easiest to understand, and then to ascend to knowledge of the more complex.

4. To make enumerations so complete, and reviews so comprehensive, that you may be assured that nothing is omitted.

The Art of Making Sense .. lionel Ruby

BLOOM'S REVISED TAXONOMY

Using the updated **Bloom Taxonomy,** we can create questions around the 6 levels, starting from the lowest level to the higher order thinking skill:

Elements	Verbs	Questions
Creating Generating new ideas, products, or ways of viewing things	Designing, constructing, planning, producing, inventing.	Compose an engineering song, skit, and poem or rap to convey the story in a new form.
Evaluating Justifying a decision or course of action	Checking, hypothesising, critiquing, experimenting, judging	Assess whether or not you think this really happened.
Analysing Breaking information into parts to explore understandings and relationships	Comparing, organising, deconstructing, interrogating, finding	Differentiate between how the child reacted and how you would react in each story event.
Applying Using information in another familiar situation	Implementing, carrying out, using, executing	Construct a theory as to why this was special for the child.
Understanding Explaining ideas or concepts	Interpreting, summarising, paraphrasing, classifying, explaining	Summarize what the story was about.
Remembering Recalling information	Recognising, listing, describing, retrieving, naming, finding	Describe where this took place.

Revised from: Kurwongbah School District, Queensland, Australia

http://www.kurwongbss.eq.edu.au/thinking/thinking.htm

Assessment and Goals:

- Assessment is not just a method for measuring students' thinking and understanding of a particular subject. Assessment can be a powerful approach for teaching thinking as well. Teaching thinking through assessment helps set standards for the types of thinking performances that lead to deeper understanding.
- Thinking-centered assessment provides information on students' understanding performances by highlighting both the strengths and the weaknesses of students' thinking. Such information is crucial for helping teachers develop follow-up lessons and instruction.
- Teaching thinking through assessment helps provide teachers and students with a common set of tools they can use to communicate and articulate their ideas about what's good and not so good about their thinking. Teaching thinking through assessment helps teachers consider and specifically target the types of thinking they value in the lessons and projects they develop.
- Teaching thinking through assessment gives teachers a number of thinking-centered lenses through which to examine students' thinking and understanding performances. Employing a variety of thinking-centered assessments also helps students better gauge how well they are thinking and learning.

Project Zero ... Harvard Education Graduate School