Engineering and thinking skills, … the missing link?
Using interdisciplinary learning to engage PreK-5 grade students.

Abstract: Educators can make changes that will improve learning for students in the 21st century. We can connect stories (from literature or social studies) that children are reading to math and science using thinking skills and the engineering design process to engage their learning. Bringing different subjects together is a natural way to provide an interdisciplinary environment that fosters a creative and exciting learning environment which allows children to see the relevance and take ownership of their learning.

Article:

Over the past few decades we have been inundated with news articles and major surveys about the education of our students (*A Nation at Risk – 1983)*. Most of it has been negative, stating that we are falling behind other countries in our competency in various subjects. In addition, there has been a great deal of research about how our children learn and how we can improve the situation. Few of these new approaches have been brought together as a system, introduced and assessed to see if they will improve our learning. At the same time we have embarked, mainly driven by our politicians, to setting content standards for teaching and devising mostly multiple choice tests around content to evaluate what is working or not. These assessments focus on the lower order thinking skills, ”remembering” versus the higher order skills of analyzing, evaluating and creating. They also don’t encourage quick feedback to learn and improve. How can we focus more around all these inputs and improve our education policy?

Public education started out as a result of the industrial revolution to both educate/train our future workers and, in reality, to keep them out of the work force until a certain age (less competition to older workers). Our models for teaching were based on the factory environment at the time and therefore we had bells and fixed classroom for teaching. It was a time of “filling their mind with content”, not teaching them how to learn, "Education is not the filling of a pail but the lighting of a fire." …W. B. Yeats. Content was not changing very fast and the educational norm used discipline and rewards as a motivation for learning subject matter.

Children in the early grades of preK to kindergarten are natural learners but lose interest as a result of this factory model of teaching as they grow. Although some of our children excel in this environment when good teachers engage them, many do not. Today, school has become the predominate source of education due to two parents working and the loss of free play after school due to parents fears for their children’s safety. In addition, the rapidly changing technologies of social networking are causing our children to tune out their formal schooling for the informal learning group of their peers. The factory model of learning separate content causes children to see little relevance in what they are taught. They want to know if “this will be on the test” and/or how are they going to make money. We need to combine our educational research and 21st century needs and/or to provide the tools for teachers to create a better learning environment. These tools can be used to engage our students, demonstrate

relevance and build on the foundation of how younger children learn. Many of us learned through play when after school we would play (interdisciplinary) games and make up rules and procedures to play the games. We were engaged and excited in the activity. We need to re-capture the child owning their learning environment. *Education is not a factory model and the children are not a vassal to fill but come with pre-knowledge ... Dave Perkins*

In today's competitive work world there is less need for factory workers and a greater need for creative knowledge workers who's skilled in content as well as thinking skills of creativity, critical thinking, reflection and the ability to ask provocative questions. We need individuals who can reflect of their learning process in order to continuously improve. These skills focus around the divergent thinking skill of developing many potential solutions and using convergent thinking to focus on a few possible solutions. Mistakes and failure is a way of learning, not something to avoid. Without taking risks, no good solutions will occur. Thus the creative thinking skill develops the divergent thinking and the critical thinking helps to find the best solution. Soft skills such as working in collaborative groups and communication skills are equally part of the mix. How are we going to get our students excited about learning and see the relevance of it all?

In our original factory environment, we operated within "Silos" of organizations. We had different departments and most did not communicate with other working departments. Thus, we had sales not talking to engineering or marketing and engineering not talking to manufacturing. No wonder we had issues in our industries. Things are changing in industry because of the competitive pressure of the world economy. The same problem exists in the area of education. This is not only with in public schools but in higher education as well. The collaborative approach of our best businesses is a model for quality education as well.

Our learning should be more interdisciplinary. Content classes need to be supplemented with real world projects that tie the subjects together. This will provide the relevance that students will see how the math and science they are learning relates to things they know about. We need to create projects that will cross different content areas plus engage our students with thinking skills for the 21st century. Our schools must be where learning is welcomed; a culture which honors curiosity and skepticism, one in which students and teachers are challenged and excited. Wonder and skepticism—"their harmonious marriage"—ought to be a principal goal of public education (Sagan, 1996, p.306). One way is to use the engineering design process as well as the thinking skills to connect the literature that students are reading with math and science using the definition that **"Engineering is about designing useful products and process for society based on all disciplines but mainly math and science."** We envision a supportive curriculum in which one of the ways students responds to literature or history is through engineering design projects as shown below in the table.

Design Process	Thinking Skills	Comments
Finding design challenges	Questioning	What's the problem
Lots of ideas	Creative thinking	Brain-writing
Convergent process	Critical thinking	Decision matrix, Requirements
Building/testing/reporting	Reflection	Sketches /feedback

They identify needs that the characters have, create multiple possible solutions, and by explore and refine those solutions through prototyping and revision.

We need to provide an environment & scaffolding for the students to experience the following:
•Imagination
•Have doubt and wonderment
•Testing / Failure experiences
•Consultation / Collaboration
•Extensions, Refinements and Elaboration
•Synthesis
•Thinking skills development (creative, critical, questions and meta-cognitive reflection)

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. Teachers need to model the ways to find design challenges in children's literature, starting with fairy or ethnic tales in the younger grades to more age appropriate stories in the older grades. Children working can be challenged to work on these design activities. Using provocative and engaging questions around creativity and critical thinking, students can probe and poke through these design challenges in a playful and learning way.

By creating these projects and involving students in finding design challenges and creating some of the rules of the project team, we begin to give students ownership of their own learning. In this way we:

- ***Promote higher-order thinking skills.*** *Meta-cognitive and cognitive skills are multi-leveled and fully integrated into the design process.*
- ***Invite the incorporation of instructional technology into the curriculum*** *Excel, Word, and Power Point, along with Smart Board technology, and use of peripheral devices such as scanners and digital photography, are all easy to incorporate into engineering projects.*
- ***Offer an "in" for learners of all types****. Due to its project-based nature, there are many roles that students can play on a design team. Students with widely differing skill sets and abilities all find a niche.*
- ***Rich cross-curricular possibilities.*** *Engineering and technology are always embedded in social contexts. Educators can use the rich social contexts of technology/engineering to tie in meaningful learning in related content areas.*

- ***Integrate with math & science showing students how and why math& science is relevant and useful in the world.*** *Engineering counteracts the "Why do we need to learn this?" question that students always complain about.*
- ***Directly connects engineering with improvement of living conditions/safety/health and welfare of people.*** *Engineering can provide relevance to students' lives and the world outside the classroom. Students can explore authentic problems and issues, connect their learning to real issues in their local community, tap the knowledge and resources of local experts, and make a meaningful contribution to their school or town.*

By using the design process model for this supplemental learning, we illustrate/model how other professions i.e. medicine, finance, engineering, scientists, architects and mathematicians use thinking skills in their work. This starts to open the possibilities of students seeing the opportunities of careers in many creative areas.
Our teaching needs to include ways to show students how to think more skillfully. We all have the ability to think but we need to show students how to get better at this skill. Part of this supplemental learning is to build a "mirror" for our students to show them how they are doing at developing their thinking skills. It is important to provide assessment skills to provide feedback during the learning process. Learning how to ask good questions is not something that we are all born with but rather a skill to learn. Our students should be part of knowing what the central learning mission that is being given to them and they should be part of creating how we should measure the success of that goal. It is by there involvement with the lesson that they will take ownership of their learning process. The story is told that Isidore Rabi, the Nobel Prize Physicist would say of his mother; … Every other mother would ask after school " So? Did you learn anything today?" But my mother always asked me a different question. "Issy' she would say, "Did you ask a good question today"

In summary, teaching in the 21st century will be different than the factory model of the past. Content still matters but now we need to include the process of learning as well and the student's engagement in that learning. We need to supplement the learning environment with interdisciplinary project based lesson that use the design process and thinking skills as the connection between subjects. The learning has to engage our students in the activities and they have to be part of finding the design challenges and creating the assessment strategies. Assessment is more than giving a mark at the end of a course but an involvement of the students in knowing what is expected and creating a feedback mechanism for learning during the course. Students need to see the real world relevance of what they are doing and build a collaborative environment with new technology tools.
Our teachers must see this new learning environment where all children can learn but in some cases in different ways and times will help them be a great facilitator of learning in the 21st century. In addition, students must be shown that people are not born with a fixed intelligence but it is through effort that we get more intelligent. Our new learning environment allows for many new opportunities to engage students. Students can be shown the benefits of keeping a design notebook to record their sketches, observations and questions.

In addition, art projects can be created around the design challenges. With our student's new thinking skills, the opportunities are there to create an engaged society.

"Children must be taught how to think, not what to think." Margaret Mead

Resources:

Victorian Curriculum & Assessment Authority www.vcaa.vic.edu.au
Mary Taft *teacher in Wilbraham, MA*
Sean Brophy; Advancing Engineering Education in P-12 Classrooms, Journal of Engineering Education July08
Dweck, Carol Self-Theories, Psychology Press, 2000
Gordon, Bernard, What is an Engineer?, European Society for Engineering Annual Conference, 1984
Gardner, Howard, Multiple Intelligences, New Horizons, 2006
Perkins, David, Visual Thinking

