An Overview of Engineering as a Learning Strategy

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WISEngineering is an online learning environment that uses informed engineering design pedagogy. Informed engineering design is a pedagogical approach that engages children in the development of knowledge and skills relevant to the design challenge at hand. This approach requires that children apply understanding and knowledge to create *informed* design solutions rather than use of trial-and-error problem solving. Understanding and knowledge are learned in a just-in-time manner through explicit learning events called knowledge and skill builders (KSBs). KSB's provide structured inquiry learning about key STEM concepts that underpin the design challenge. An example re designing a solar oven is presented in Table 3 at the end. For home schooling, we will include with most KSBs links to expanded investigations, allowing the creation of deeper learning should a particular topic intrigue the learner. An important feature of WISEngineering is that the parent is in control of the environment, you will have to ability to allow your child to work with others, or not. The WISEngineering environment allows for a variety of assessment strategies—multiple choice, short answer, and extended response. All are graded using artificial intelligence that we have built into the environment. Your child will always have the opportunity to revise and revisit topics.

K-12 Engineering

What does engineering mean when it is included in STEM? How is it different than the practice of engineering in the business world? One way to begin to understand engineering in a STEM is to look at the differences in thinking in the fields of math, science, engineering and social science/humanities. These differences are displayed in Table 1. As can be seen, science is the study of the natural world, a discipline engaged in discovering the whys and wherefores of natural phenomena. The process for this investigation is scientific inquiry, in which a hypothesis is posed and logical investigations are undertaken to confirm or deny the hypothesis. Mathematics has its own philosophy and patterns, which are also often used by engineers and scientists to model designs or to represent natural phenomena, such as Newton's second law of motion (Force = mass * acceleration**)**. There are rules of mathematical analysis and theorems that allow for the manipulation of such equations. A publication by the National Research Council, *Helping Children Learn Mathematics* discusses the big ideas and habits of mind needed to be mathematically successful. The social sciences and humanities provide an entirely different view of the world, a world shaped by human perceptions and understandings. For instance, a novel or a political or social event can by analyzed from many different perspectives. Although Table 1 presents thumbnail sketches, it highlights the differences among these disciplines and can be used to help think about the overarching themes that define engineering as both unique and interconnected to the other disciplines. Engineering within this context can be considered either a noun or a verb. Engineering can be either the discipline which solves challenges or the approach to solving challenges.

Table 1. Comparison between different fields of thought.

Engineering	Science	Mathematics	Social Sciences and Humanities
Study of the human-made world	Study of the natural world	Study of mathematical constructs	Study of human mind and perception
Engineering design	Scientific inquiry	Mathematical analysis	Rhetoric and criticism
Iterative design process, optimum solution	Hypothesis testing and evaluation	Theorems, proofs, rational constructs	Eclectic methods, comparative values
Artifact produced	Theory confirmed	Theorem validated	Opinion rationalized

Engineering, the noun, uniquely connects all three disciplines. In creating the human-made world, engineers must use knowledge from science, mathematics and the social sciences and humanities. Engineering, the verb, on the other hand, enriches and allows for informed investigation within each setting. In contrast to scientific inquiry and mathematical analysis, engineering design does not seek a unique or correct solution, but rather looks for the best or optimum solution after a variety of factors (e.g., cost, materials, aesthetics, and marketability) have been weighed. An important feature of this design process is that it is iterative, creative, and nonlinear. Furthermore, the solutions are tempered by our societal values. As a result, the optimal solution for one person may not be the optimum solution for another. In other words, there is no "one correct solution." Engineering design is a very engaging pedagogical strategy, particularly with adolescents, because children can bring their values to their design solution. Optimal solutions are also not stagnant and unchanging. For example, even if a solution were optimum at one moment in time for the specifications and constraints that were imposed, new technologies, new opinions, and new perspectives might lead to redefined or different solutions. This is a very empowering and unique feature of engineering that is in significant contrast to scientific and mathematical understandings where hypotheses and theorems may be refined but generally remain unalterable.

Another defining feature of informed engineering design is that it is not trial-and-error gadgeteering. Engineers create design solutions that are intentional and knowledge based. They use their knowledge of science and engineering science to understand what is happening physically, their use of mathematics to create models that may be analyzed, and their understanding of prior technological solutions so they can innovate. This is in contrast to the process used by inventors who typically gadgeteer along with trial and error to arrive at a workable solution that they can patent or manufacture. This use of modeling, with its inherent predictive analysis, is one of the significant differences between engineering and technology education, and engineering and art.

We have developed a framework for designing homeschooling curriculum units as shown in Table 2 and have tested the framework with the development of a Solar Oven unit.

Table 2--FRAMEWORK FOR CURRICULUM DESIGN

•Each subject (math and science) maintains its own perspective.
–Informed Engineering Design is *infused* into various math and science units—this relates to the pedagogical practice where the challenges are connected to the big idea in science or math that we wish the child to learn and the learning is demonstrated by the thinking that underpins the designed artifact.
•Informed Engineering Design Pedagogy is introduced multiple times within different science and math lessons to allow for transference of understanding of concepts. Engineering design is a terrific problem solving strategy; children will learn about engineering design problem solving by using the WISEngineering environment; e.g. specifications relate to what a design must possess or accomplish.
•The Math topics, the Science topics, must be challenging for children and key for later understanding of more complex math or science concepts. While time is not necessarily an issue, spending time and resources on a design solution needs to relate to essential topics, not ones that nice to know, or easy to learn.
•Informed Engineering Design fits naturally within the science unit or math unit. Not all topics are amenable to design solution, e.g. theorem/proof.
•Science units, or math units, must be taught in an inquiry based way and be of long enough duration to allow for students to engage in meaningful hands-on activities.
•The WISEngineering curriculum units are designed to be stand alone units, providing sufficient support within the environment so that parents are not required to knowledgeable about the content. However, there will be information for parents about the unit, a meta-level of understanding of the big ideas and goals for the unit.
•All lessons are aligned with the Common Core Math Standards and the Next Generation State Standards to assure the lessons have face validity. We view the standards as the floor, not the ceiling; a starting point for the curriculum design.

The overview of the Solar Oven design challenge is provided in Table 3.

Table 3—Solar Oven Curriculum Example

We can capture solar energy and use it for cooking in a device called a solar oven. We will examine solar ovens from a humanitarian perspective and apply knowledge of physics to create a solar oven. Solar ovens have helped and have the potential help more underdeveloped countries use the sun as an energy source for cooking. (include links to sustainability). There are many physics topics to understand in design a solar oven: the sun's angle of inclination to the earth throughout the year; angles of incidence and reflection on mirrored surfaces; the energy in the sun's rays; the greenhouse effect, emissivity of surfaces; radiative and conductive heat transfer and insulation; and conservation of energy. In terms of math topics, children will need to use simple algebra in science calculations e.g. the amount of energy a solar oven can collect; use protractors for angle measurement.

Children will investigate all of these topics using KSBs and their learning is checked within the WISEngineering environment. There may be the use of simulations and animations, as well as experiments to perform.   If there are techniques needed for construction (cutting, attachments, materials) of the solar oven components, these can be demonstrated with photos and videos.   A goal is to use inexpensive materials in the project.