Session 1280

K-12 Education and Systems Engineering: A New Perspective

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In a classroom in the suburbs of Boston, a class of first-graders are designing snow removal equipment out of LEGO Dacta materials. Before breaking up into groups, they are having a class discussion about different types of equipment - shovels, plows, front-end loaders, etc. One boy raises his hand and says "Can we make up something different? I mean, can we just design something that hasn't been made before?" The teacher answers yes, and the boy turns to his LEGO partner and says "We are inventors!"

"To understand is to invent." - Jean Piaget (in Papert, 1993)

Introduction

A New Perspective

As the highly successful "Central Park East" school in Manhattan claims in their mission statement, a worthy goal of education is to graduate students that can see and understand the world from multiple perspectives. For problem solving and design, it is advantageous to hold multiple ways of viewing a problem and be able to shift between those views. For working in a cooperative learning group, being able to put yourself in the place of another facilitates communication and increases ones interpersonal skills. The main subjects currently taught today in K-12 education: science, math, English, and social studies, are but a select few of the perspectives or different ways of thinking and knowing that exist. With technology becoming an increasingly important part of our lives and a part of the education of our children, the absence of the content and processes of one subject has become increasingly evident over all others: engineering. An "engineering perspective" can be a fascinating lens through which to look at the world around us that is ever increasing in complexity. Whether it is the rack and pinion in your ice-cream scoop or the processor in your desktop computer, examples of engineering are everywhere.

By encouraging children to look more deeply at the artifacts around them and engage them in the making of such artifacts, they will be developing their “engineering intuition” and learning to use this "engineering perspective" as their own. In addition, many of us would like our children to grow up with the knowledge and skills necessary to get along with others, which calls for more of the curriculum to be socially constructed. Systems engineering is such a pedagogical model that goes beyond seeing engineering as a design contest between groups of students and into a cooperative venture between all students. Systems engineering design involves all students working together and flows from defining requirements and exploring alternative concepts to turning the requirements into a model and testing it. There is a shift in mathematics education to encourage students to do mathematics the way that mathematicians do it. A Systems engineering project in the classroom is doing engineering the way engineers do it.

Systems engineering is not only good for education in terms of the good it can do for students, but for education as a whole as well. Education is a system like many other types of systems, and needs to be designed with a systems approach. The questions that education reform efforts should be asking are ones such as "what are the functional requirements of education?" - the first question in a systems engineering design task. In fact, there are projects and institutes thinking in exactly this way (ASCD Systems Thinking Newsletter, 1996).

Engineering and Educational Philosophy

If John Dewey were opening up his famous Laboratory School today instead of 100 years ago, the occupational theme that teachers would use to teach children "how society has grown to be what it is" (Tanner, 1997) would not be sewing, cooking, and carpentry, but engineering. With an enormous interest in the social nature of learning and educating children that can live and work together, Dewey certainly would have been a fan of systems engineering in particular. Dewey believed that a child's natural impulses to create and investigate are a great educational resource to be tapped, and that education should coincide with a child's interests and developmental stage. A young child is "inherently active with strong impulses to investigate, to share with others what they have found out, to construct things, and to create," (Tanner, 1997) Dewey believed, and the opening quote supports that belief. Dewey believed that "Children simply like to do things and watch to see what will happen," and that children do not understand scientific activities as the means to arriving at "abstract truths" about the universe (Tanner, 1997). A child's developmental stage is thus more like a natural engineer than like a natural scientist.

One of the main tasks of educators today is to make subject matter more hands-on and more relevant to student's lives. What has yet to be accepted is that engineering is very much a hands-on subject and engineering *is* real life. In his curriculum, John Dewey used real world problems as projects. Students worked on defining the problem, made observations necessary to solve the problem, etc., much in the same manner that a systems engineering project is undertaken. Dewey believed that learning should be as close to real-life as possible and not just a preparation for the future. He also believed that children in schools should be engaged in the types of activities that reflect the life of the larger society (Tanner, 1997). Although some aspects of Dewey's progressive philosophy have taken hold, engineering of any kind is not truly represented in K-12 education even though it is now the second most popular job in the country (ASEE website).

What is Systems Engineering?

"Systems Engineering is the art and science of decision-making" (USMA website)

Systems Engineering is the popular interdisciplinary approach to the design of a complex engineering system. Beginning with certain needs, decisions are made by groups of engineers as to how to best meet those needs. Engineers normally are experts in one discipline of engineering: mechanical, electrical, chemical, aeronautical, etc., But for a complex system, aspects of every type of engineering need to be integrated together. Just as the electrical and mechanical components of a system need to function together, the electrical and mechanical engineers need to communicate with each other to design a working system. There are also engineers called systems engineers who work to coordinate communication between the other groups, as well as define the overall system requirements. Groups of engineers have to make tradeoffs when trying to satisfy as many of the requirements as possible, and therefore there is never a "best" or "right" answer or only one solution.

An Example of Systems Engineering and Systems Engineers – The Wright Brothers

In order to build, test, and pilot the first successful airplane, the Wright Brothers not only had to be scientific, they had to do some systems engineering. We learn about the Wright Brothers in history class, but never study the process that they went through to arrive at their design. We admire great engineering feats such as theirs, but essentially, we graduate "engineering-deficient" students incapable of recreating them.

The Wright Brothers are a favorite example to talk about when mentioning feats of the 20th century and technology. Seymour Papert has used the Wright Brothers as examples of people that needed a "technological infrastructure" before they could be successful and took their problem apart and solved separate pieces of it one by one (they built a wind tunnel and tested model wings before trying to build a plane) (Papert, 1993). These two examples are both aspects of what systems engineering is about - but there is one more. When designing something brand new from the ground up, it is often useful to follow the phrase “form follows function”. Many airplane designers before the Wright Brothers did not, and did not have successful flights. These unsuccessful planes were in the form of a bird, machines that flapped enormous wings. The Wright Brothers instead broke down the functions that the airplane needed to accomplish, and designed a device to meet those functions. A bird uses wings to go forward as well as to get lift, which are two different functions. The first successful airplane had two distinct physical components to meet these two functions: the engines and the wings. (University of Arizona website).

Why has Engineering been historically absent from public education?

Plato's Republic has been one of the most influential works for public education up until today. Plato, like Piaget, emphasized abstract thinking as the ultimate way of thinking and knowing. Science, which might be seen as the search for abstract generalizable truths about the universe, is the epitome of such thinking. This could shed some light as to why children have "science class" and no "engineering class". Even Leonardo DaVinci, who is often seen as a great engineer of the past, never wanted to "get his hands dirty". A lot of his designs and inventions were never actually made because the technical and "engineering" aspects of invention such as model making were considered beneath him (Gille, 1966). Plato took this to an extreme, saying that any thinking done about the physical world wasn't useful.

The Concrete and the Abstract

A primary concept in systems engineering is the relationship between the abstract and the concrete. When designing a complex system, it is often helpful (as with the Wright Brothers) to think of functions (abstractions) first instead of components (concretizations). If you ask a child what is needed to make a vehicle, she might start rattling off a list of familiar components "tires, steering wheel, doors, horn," etc. that belong to a car. What is often useful in design, however, is to think of vehicular functions (means of motion, means of changing direction of motion, etc.) in order to brainstorm all of the possibilities and not get locked into one way of thinking. This is what is often called top-down design. Bottom-up (or concrete to abstract) design is also useful in systems engineering. When designing a rocket for example, it is more cost effective to choose between existing rocket engines (highly complex pieces of machinery) then to design one from scratch. The term "off-the-shelf" is often used to describe a component that came from a "bottom-up" design decision.

Systems Engineering and K-12 Education

Interdisciplinary

Systems engineering is naturally interdisciplinary. An engineering project not only requires math and science skills but reading, writing, and presentation skills as well. Engineers today cannot rely on scientific and mathematical knowledge alone. They often need a good understanding of politics, management, human factors, as well as the environment, as these factors are always figured into the requirements of a good system.

Various facets of engineering are already present in schools. When a student learns about perspective drawing and orthographic projections in art class, designs an experiment in science class, studies ancient inventions and inventors in history class, or makes a presentation of a paper in English class, they are doing parts of systems engineering in short, fragmented pieces. Imagine the power of incorporating all of those talents together in one task. Consider the following quote about Dewey's Laboratory School:

> When children made things, they learned history, science, and mathematics through invention. Science, art, and culture were one. There was thinking involved of the most fundamental kind: continuous observation of materials, planning, and use of the hands. The thing that was cultivated was the mind's eye. There were appreciations as well, for beautiful objects and inventions, because one learned at first hand how hard it is to make them and the thought involved (Tanner, 1997).

Child-Centered

"The most important thing you learn at school is that learning only happens by being taught" (Illich in Papert, 1990).

The teacher has moved from the "sage on the stage" to the "guide on the side," because the former mode of instruction teaches students to be dependent on an authority (Cummins and Sayer, 1995). A systems engineering project assists such a child-centered learning environment, where the problems often are not only figured out by but *defined* by the students, and design decisions are made not from a teacher or a leader, but collaboratively by all students.

Tradeoffs and the Relationship of the Parts to the Whole

"In general, a subsystem cannot be considered in isolation from the other subsystems" - Charles Samson (in Panitz, 1997)

In an engineering project, you work on the design of one aspect of a project in relation to other aspects of that project and never on its own. Often, various aspects of a project cross all of the traditional disciplines, making it a difficult problem. Since everything is interrelated, you cannot “isolate one variable” as with a science experiment, but rather seek ways to make the best compromises between what every aspect of the project requires. Systems engineering thus fosters decision-making skills and the ability to weigh alternatives. Not only do students need to make decisions about the project itself, they need to make decisions about the kind of thinking they might want to employ at a given stage in the design, turning students into epistemologists (Papert, 1980).

In a systems engineering classroom, you cannot only consider your cooperative learning group and ignore what everyone else is working on because every group cannot optimize their own work. The following example illustrates this phenomenon: "Designing the sturdiest aircraft structure would actually harm the overall system, causing the aerodynamics to suffer greatly and drastically reducing the plane's speed" (Panitz, 1997) In other words, if planes, like cars, were built to survive crashes, the plane would never get off the ground. Tradeoffs have to be made.

Critical Pedagogy

Critical Pedagogy opens up critical social issues for students to discuss and think about (Cummins and Sayer, 1995). Students ask and are asked critical questions that deal with issues such as race, justice, multiculturalism, and poverty. Systems engineers are involved with this kind of critical thinking in their daily work. Not only to systems engineers need to consider the technical aspects of the design, but "relevant social, political, environmental, legal, and ethical issues" (Samson in Panitz, 1997) are always involved.

Designing as well as Building

Engineering projects in schools tend to concentrate on the "building" aspect of engineering. Projects are usually graded on their final results alone, putting less of an importance on the design and more on the final complete artifact. Also, the criteria for success on such projects often does not mimic a true engineering figure of merit (FOM) as well. For example, requiring that students build the “strongest bridge” out of popsicle sticks without requiring the bridge to also be “low cost,” students might build bridges that are simply a big glob of wood and glue … strong, but not too economical. Too often the students are left alone to do all of their own designing for the sake of letting them be creative, yet the students don’t receive any guidance or direction as to what the design process is.

Emphasizing the "building" aspect of engineering also alienates the girls in a classroom. Boys tend to excel in building activities, having had more experiences with toys that encourage building activities. Telling a girl to "build" something without giving her the tools of design to work with will result in her panic and withdrawal from the situation. The toys that are marketed towards girls encourage the design of their play more than actual construction. They often "design" their play to the point that most of their time playing is spent setting up the rules.

Cooperative, not Competitive

In a systems engineering task, everyone is working together toward a common goal. There are cooperative learning groups of students working on different sub-systems, but they all have the overall interest of the final product, or "system", in mind. Design tasks that split students into cooperative learning groups to each design a similar artifact can sometimes have disastrous results. In one study, students created their own competition during a design project even though the performance of their design wasn't a major factor in their grade. Students did not share ideas with each other and didn't focus on understanding as much as they did on performing. (Baumgartner and Reiser, 1997)

A Community-Building Activity

While cooperative learning is being used increasingly in the classroom, it can have disastrous effects if implemented badly. A class of students first must get to know each other and communicate with each other as a whole unit before being thrust into a foursome for the school year. Systems engineering brings cooperative learning to a new level, where different groups must communicate their wants and design decisions to other groups, and make such decisions together. Cummins and Sayer even use the phrase "interdependent cooperation" to define what it means to have "progressive pedagogy": enhancing academics as well as inter-personal relations (Cummins and Sayer, 1995).

Fred Martin has noted in his work with LEGO "Programmable Bricks" that students gain experience in the field of systems engineering for the first time with these bricks because they are exposed to mechanical, electrical, and computational elements at once (Martin, 1996). Kids tended to divide themselves into groups of programmers and builders. There probably was much communication that had to go on naturally between these students. Systems engineering is a process that provides the classroom structure to create those divisions for students and provide an overall structure for the design process. Systems engineering forms an environment centered on the "collaborative generation of knowledge" (Cummins and Sayer, 1995).

A Classroom Example of Systems Engineering - A Computer-Controlled House

One example from our project at Tufts University involves a kindergarten class in Lincoln, Massachusetts. Students planned, designed, and constructed an entire town out of LEGO bricks and other materials, complete with a computer-controlled school bus. Students learned in an interdisciplinary fashion about the town as a system: how it works, how it operates, and how it functions. The children became very involved with the project, going home at night to draw layouts of the town the way that they thought it should be designed without being asked.

The following example follows the systems engineering design process step by step. This example uses Lego Dacta materials and Lego Engineering, a software package developed at Tufts University through the LDAPS project - Lego Data Acquisition and Prototyping System (see the Appendix for more information).

Before you begin a systems engineering project

Without any preparation, a large design project may seem daunting to students at first. Provide students with mini design problems first before beginning a systems engineering project. Discuss and allow them to get a feel for things such as gear ratios and friction. Take time for the students to learn the names of different tools and parts and what they do. Mini design problems also allow students to experience every facet of a design. For example, you don't want to jump into a systems engineering project to make a motorized drawbridge where some students learn about structural design yet nothing about motors and electricity. Talk about both topics with all students first.

Secondly, find examples of engineering from the real world to talk about. Take simple things like diet scales or wind-up toys apart together and figure out how they work. Get your hands dirty. Put engineering in its global and historical context and link it to other things the students are presently studying. Talk about what real engineers do. Find a parent that is an engineer and invite her into your classroom to talk.

Starting a systems engineering project

The entire process of systems engineering should be laid out to the students at the start of the project. A time-line of dates for design reviews and a block diagram of the steps involved should be established so that the students have a sense of schedule. Each student should keep a research notebook where they record all of their ideas and decisions. A section of the room should be cleared aside for building. Keeping a bulletin board for groups to post messages to each other and keep a record of progress is also helpful. Realize that at each step of the process, the students can become more autonomous and self-governing.

Systems engineering provides students with a holistic approach to problem solving and thus can combine as many or as few different disciplines as desired. The steps involved in organizing a systems engineering project are many, and success is never guaranteed. Steps may be dropped at the teacher's discretion, and of course modified to fit the level of the students. The following ten steps are a guideline for an example systems engineering project geared towards a high school class.

1) Problem Definition.

The Problem Definition is a clear and concise statement of need. This statement will often come from the client or boss (teacher), although it would also be good to brainstorm a good design problem with the students. If possible, make the system as "real world" as possible. Do the plants need to be watered or a pet fed on a schedule during school vacation? Do you need a good way of keeping track of how many days a student is absent? (systems don't have to be tangible!) You might even want to set it up as a meeting between client (teacher) and engineering firm (students).

Example: A model of a high-tech house is needed to present to the customer by the end of the semester.

2) Identify the primary objectives.

The primary objectives are the main goals that you want your system to accomplish. Like the system definition, these can have teacher and student input. Depending on the scope of your project, you may have secondary objectives as well, or multiple uses for the same system. Once the problem is stated and students have started to think about the system's objectives, they can begin doing research in the library or on the web about such systems.

Example: Primary objectives: Provide shelter, protection, warmth, and storage. Task: start reading books and looking at pictures of lots of different kinds of houses.

3) Define the key (system) requirements.

The key requirements are the attributes and capabilities that the system must possess: the "mandatorys" or "needs". The requirements are based on the primary objectives. The aesthetics and other non-critical requirements should also be established as the "preferences" or "wants". All designs must satisfy the "needs", but might not satisfy all of the "wants".

Specific requirements stated as functions are called Functional Requirements. There are five main types of functional requirements: performance, safety, regulatory, cost, and infrastructure.

Example:

needs:

1.1 performance: able to provide light and electricity
1.2 safety: protection from weather
1.3 regulatory: does not violate building codes
1.4 cost low as possible
1.5 infrastructure: minimize necessary infrastructure beyond home (i.e. get power from city instead of constructing a windmill, if possible)

wants:

1.6 performance: computer-controlled
1.7 safety: protection against burglars
1.8 regulatory: wheelchair accessible
1.9 cost: low life cycle cost (i.e. low maintenance)

1.10 infrastructure: provide recreational space outside the home.

For each "want", there should be a figure of merit (FOM). For example, is low cost worth the same to the customer as high quality? Or is it more important? These figures of merit will help the students pick among alternative designs by weighing the requirements and making tradeoffs. A simple 1-5 scale could be used to give the FOM's values. For example low-cost may be a 1 (top priority) while wheelchair accessibility (assuming nobody in the family buying the home is a wheelchair user) might be a 4.

It is at the beginning of this step that the class, depending on initial class size, may be broken into groups for managerial purposes. Requirements defined by different groups can be compiled together for the groups to use in step 4.

4) Explore alternative concepts.

During concept exploration, divide the students into groups (groups of four recommended) and have each group come up with a different conceptual design solutions to the problem. This involves looking at existing designs, brainstorming, and coming up with analogies to the problem at hand. Choosing among options fosters what Harel and Papert call "cognitive flexibility" - the ability to search for different (and better) alternatives to a design problem, and even discard ones that aren't efficient (Harel, Papert, 1996). Along with concept exploration can come a discussion of what the 'design parameters' are: variables such as size, material, mechanism, shape, color, etc. Other tasks during this phase are outlined below in what is required for the first presentation.

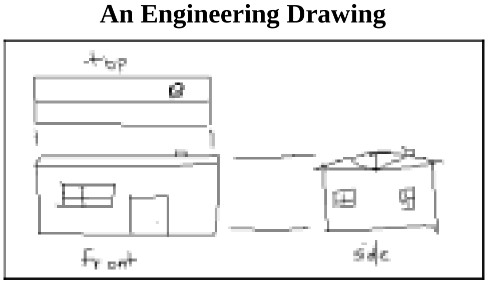
First Presentation: Concept Review

For the concept review, each student group makes a presentation to the class about their design. This can include a name for the project, the showing of drawings and preliminary sketches, a discussion of how they arrived at their design, ideas they discarded, tradeoffs they have identified, a beginning system block diagram of the different subsystems (including interfaces), a functional flow diagram (how the functions and/or activities of the system change over time), and how the group concept is derived from the main objective.

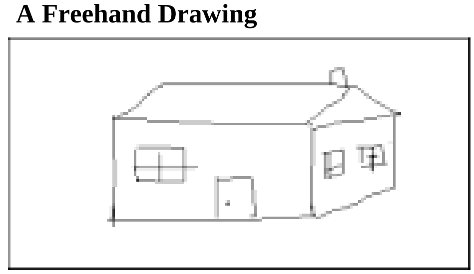
Example:

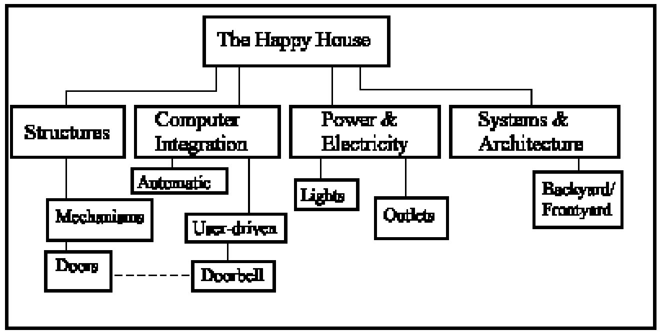
Engineering drawings involve three views of the object, while a freehand drawing is three-dimensional.

An Engineering Drawing

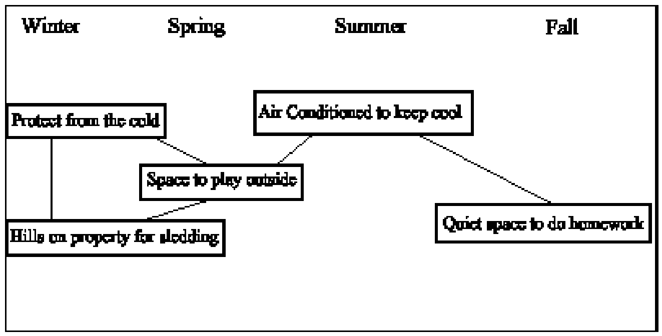


A Freehand Drawing





System Block Diagram (partial), interfaces are dotted lines



Functional Flow Diagram

After the concept review, students should be active in discussing the alternatives. Instead of a contest of which design is better, this can be a method of choosing the best aspects from the different designs and putting them together. There is never an 'optimal' design for a complex systems engineering project. There are always tradeoffs.

"There is never a single right solution. There are always multiple wrong ones, though."

5) Functional Decomposition.

At this stage, students should be broken into groups according to interest where each group is a subsystem. One group should serve as the "systems" group, acting as coordinators and organizers of the other groups.

Example: structures and mechanisms (using Lego bricks, gears, joints), computer control and integration (using Lego Engineering, computer interface boxes, sensors and motors), systems and architecture/human factors (coordination of other groups, general layout and plan, scaling to humans), and power and electricity (wiring, batteries, lighting)

The systems group expands the list of systems requirements and numbers them. The other groups must come up with a list of the functions of their subsystem that map to the system requirements. After mapping functions to system requirements, actual physical components are mapped to the functions. A pyramid can be made with "system" at the top and "components" at the bottom, similar to the system block diagram.

Systems engineering uses a top-down approach. It naturally moves from the general and the abstract (functional requirements) to the specific and concrete (physical components). If you have decided from the beginning to use specific hardware and software, however, as is the case with our Lego Engineering example, you must include some bottom-up design as well. You must keep in the back of your mind the tools you have to deal with as you think about the different design possibilities.

Second Presentation: Preliminary Design Review

In the PDR, each subsystem group presents a system block diagram and the results of their functional decomposition.

System block diagram

The system block diagram is a hierarchical pyramid-like diagram of all of the segments, subsystems, and components of a system. Each group should concentrate on their branch of the block diagram only. Each subsystem group identifies what their main components are, and sub-components if necessary.

Results of functional decomposition

Each requirement of a subgroup should refer back to a system requirement.

Example:
Structures and Mechanisms Group (2.0)

2.1 Provide a sturdy primary outer structure (1.2)
2.2 Provide a means of access other than stairs (1.8)

The numbering system used can later be used as an outline for the final report, which students can start writing now.

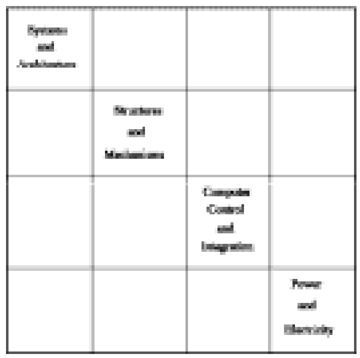
6) Initial sizing and design & Interaction diagrams.

"Not having all the information you need is never a satisfactory excuse for not starting the analysis."

Initial sizing and design

While starting to build, students should be doing a good deal of designing and planning. If a model is being built, students need to decide on a appropriate scale. If the system involves physical structure, an estimate of the loads (forces) that it will be subjected to should be made. The systems group should begin to estimate the life-cycle cost, assess possible safety concerns and risks, and establish a detailed time schedule. Students might find it difficult to begin any kind of design without knowing what the other groups are doing. For our house example, this might mean that the structures group cannot build the walls until it knows how many outlets per room to leave holes for, yet the power and electricity group might not know how many outlets they will use until the computer control and integration group tells them how many ports on the Dacta computer interface boxes are available, and on and on... This is where the interaction diagrams come in.

Interaction (N2) diagrams



N2 diagrams help to organize communication between groups. The diagram displays the kind of information each group needs to give each other group.

Example:

Anything to the left or right of your group's square are the "outputs", or information that you need to give other groups. Anything below or above your group's square are the "inputs", or information that you need to have from other groups. The N2 diagram can be displayed on a large dry-erase or chalkboard, or up on the bulletin board throughout the project. Even with an N2 diagram in place, it is hard to begin design. Groups can't get certain information until they get some... and they might run into the same problem as before. What our young engineers must learn at this point is how to guess and estimate. Like writing a story, where you get all of your ideas in order and write a rough draft, engineers often must make a "first guess estimate" of a design, and constantly modify it. Engineering is an iterative process.

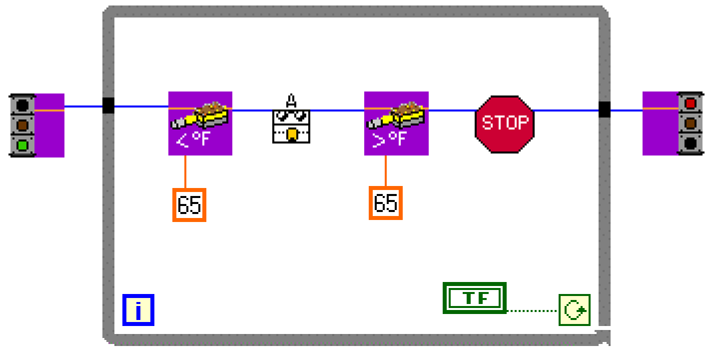
"Design is an iterative process. The necessary number of iterations is one more than the number you have currently done. This is true at any point in time."

Third Presentation: Critical Design Review

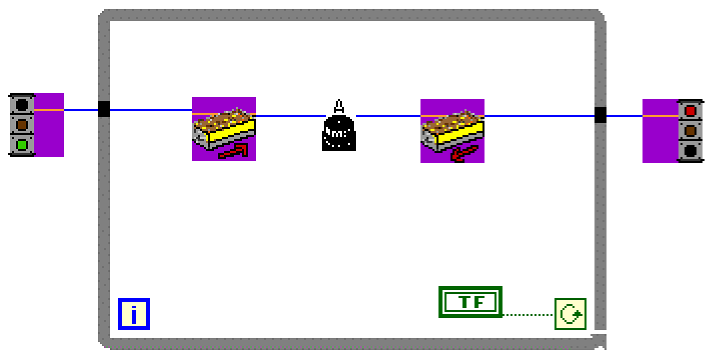
In the critical design review, each group should present their subsystem designs. This review is more of a "this is the design" kind of presentation, instead of talking about alternatives or tradeoffs. Students should get to fill out evaluation forms on each presentation. What questions to they have about the presentation? What issues still need to be resolved?

7) Building a Model/Manufacturing

Example Lego Engineering Programs



An Example Computer Program to Regulate the Temperature of the House. If the temperature drops below 65, the light brick turns on. When the temperature is above 65, the light goes off. The process repeats in a continuous cycle.



A computer program to operate the doorbell on the house. When the doorbell (the LEGO touch sensor) is pressed, The LEGO sound element goes off until the doorbell is released. The program repeats continuously.

The final designs will likely still be iterated upon as the model or system is being built. Students should still continue to document changes and decisions in their notebooks.

8) System Integration and Testing

During this phase, which will be naturally tied in with step 7, system components should be tested to make sure they are operational. Students can determine the best conditions for operation (temperature, time of day, weather, lighting condition, etc.) and figure out the systems reliability (how often it works the way it should).

9) Operation

Have your system be set-up and operational for the rest of the school to see. Having it out at parent's night can be especially fun. The students could even write an "operation manual" that describes how the system works, and how to operate it. Compile all efforts into a final report that every student has made a contribution to. Make copies for everyone and include plenty of pictures. The students can have a book-signing too.

10) Retirement/Disposal

Putting the Lego bricks away is part of the process. Make sure you take pictures and throw a party!

Conclusion

Introducing Engineering into pre-college education can give students another perspective with which to interact with the world. Through toys that emphasize design and through artifacts of the adult world, children have experiences with engineering that they bring into the classroom that are underutilized. K-12 Systems Engineering in particular emphasizes the kind of interactive and interdependent group learning that fosters growth in social skills, giving children the opportunity to think and act critically in society.

"It is as inevitable as it is right and proper that they [progressive educators] should break loose from the cut and dried material which formed the staple of the old education" (Dewey, 1938)

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United States Military Academy website http://www.se.usma.edu/programs/se.htm

Appendix

The LDAPS Project

http://ldaps.ivv.nasa.gov/
The LDAPS project is aimed at improving science and engineering education through educational technology and the Internet, supported by NASA and the LEGO Group.

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Other K-12 Engineering Projects

http://engineering.dartmouth.edu/teps
Dartmouth Project for Teaching Engineering Problem Solving
Teaching science, math, and technology teachers about engineering problem solving.

http://shimano.me.utexas.edu/DTEACH.html
Design Technology and Engineering for America's Children Teacher Education Project (DTEACh)
Teaching teachers about Engineering.

http://www.che.wsu.edu/modules/
Teacher Institute for Science/Math Education Through Engineering Experiences
At this site you'll find a series of teaching modules for how to bring engineering into your classroom, written by teachers.

http://www.cc.gatech.edu/edutech/
EduTech
A multi-disciplinary research organization at Georgia Tech aimed at improving math, science, engineering, and design education through the use of advanced technology.

Definitions:

function: action or activity performed by the system

component: performs a specific function

requirement: attributes or capabilities that the system must or should possess, expressed as functions or performance measurables.

system: a collection of interconnected components that work together to fulfill a common objective (Panitz, 1997).

Quotes:

When in doubt, estimate. In an emergency, guess. But be sure to go back and clean up the mess when the real numbers come along.

A bad design with good presentation is doomed eventually. A good design with a bad presentation is doomed immediately.

In nature, the optimum is almost always in the middle somewhere. Distrust assertions that the optimum is at an extreme point.

Biographical Information:

Ben Erwin is Curriculum Coordinator for the Center for Engineering Educational Outreach at Tufts University. He received a S.B. degree in Aerospace Engineering with a minor in Planetary Sciences from the Massachusetts Institute of Technology, and a Masters of Arts in Teaching degree from Tufts University. He also holds a teaching certificate for secondary Physics. As a volunteer at an after school center, he has helped to start an Engineering Club among fifth through eighth graders. He is a regular visitor to elementary and middle school classrooms where young kids teach him about engineering. He is thankful to the Aeronautics and Astronautics program at MIT, and the Education department faculty at Tufts University.

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