APPENDIX 1-A-1

Infusing Engineering Design into

K-12 Engineering and Technology Teacher Education Programs

Sample Unit 1:

Engineering Design Idea Generation

("Creative Conceptual Design" Stage,

Using "Brainstorming Sessions")

K-12 Engineering & Technology Teacher Education Course:

ETES 2320 – Creative Activities for Technology Teachers (UGA)

(For course description, refer to UGA Website at

http://bulletin.uga.edu/bulletin/courses/descript/etes.html.

For proposed modified course description, refer to Appendix 1-C)

TECH (N 4) - Creative Activities for Engineering and Tech Teachers

(Proposed for CSULA)

(For proposed course description, refer to Appendix 1-F)

Eventual Clientele: Kindergarten to Elementary School (Grades K - 5)

Description of the sample unit (The engineering and technology creative and conceptual design projects):

Assignment (to be given at the start of the course):

In this course, four major themes of science and technology as well as related fundamental principles of science and technology will be explored. Theme 1 (Construction System) covers with types of structures and construction (*Figure 1*); Theme 2 covers Mechanical System (the six simple machines and Rube Goldberg Competition, see *Figure 2*); Theme 3 (Communication System) covers different categories of communication (human-to-human, human-to-machine, machine-to-machine, machine-to-human, and supplementary types, see *Figure 3*); and Theme 4 (Transportation) covers different environment and vehicles of transportation (land, air, water and space, see *Figure 4*).

In addition, the following design processes will be explored: (1) engineering design process (2) technology education design process; and (3) combined engineering and technology design. Standards and conventions for using engineering notebook, as well as professional engineering sketch techniques, will be studied and practiced. The main design process to be used in the assignment is the "technology education design process" (selected steps only, mainly "brainstorming").

To enhance students' creative conceptual design abilities, the following semester-long creative conceptual design project is proposed, including two components:

1. Conceptual Design (Engineering and Technology Theme Park): Design an educational and entertaining theme park, which will be used by visitors of all ages (children and adults alike) to learn and experience

   - Themes covered in the course: All or most of the fundamental principles of science, engineering and technology explored by the four major themes covered in the course, using as many topics or items covered in all themes as possible; and

   - Themes explored by students own efforts: One science, engineering or technology concept of students own choice and research; this theme will be used for the second part of the project (Curriculum Development).

   This design should be both creative and conceptual:

   - Creative: The main focus is on generating creative and innovative design concepts; students are required to (1) generate three overall designs; (1) choose one design to be further developed;

   - Conceptual: The focus is on the overall design of the whole theme park, not on the detailed design of any particular component. Student teams will use a variety of medium to record and present their design concepts: quick sketches, elaborate drawings with pens, crayons and color pencils, PowerPoint presentations, etc.

2. Instruction Unit Development: Develop an instructional unit for teaching one principle of science, engineering or technology to K-12 students. This should include: a. Plan of Instruction; b. Teacher's Report; c. PowerPoint presentation; d. Scaled model; e. Handouts for K-12 students (learning materials, home work assignment, basic principles and formulas sheets, useful Internet addresses, and others); and f. List of Reference. The component of the project is due the week before the finals of the semester. Students could find a theme to explore by any or all of the following:

    - Browsing through Popular Science and other magazines related to science, engineering and technology from UGA Science Library;
    - Browsing through any or all Internet websites listed at the end of this assignment handout, or any other websites of students' own choice;
    - Browsing through K-12 math, physics and chemistry textbooks, and popular science, engineering and technology books (a list of possible reference books and CDs is provided at the end of this handout);
    - Search through own kitchen and garage to find some an interesting appliance, device or instrument, then go to HowStuffWorks (http://www.howstuffworks.com/) and other websites, such as Wikipedia (http://www.wikipedia.org/), to find relevant information.

Organization of design teams: Students will work in groups of 4 - 5 members under instructor's supervision. Group members will work together to frame the overall research and design strategy, to divide the research and tasks among the members and to coordinate the efforts of individual members into achievement of group objectives.

Management of design teams: At each stage of the design process, each team will have a Coordinator to coordinate the activities of the members; the role of Coordinator will rotate among the team members. The Coordinator will keep a work progress log.

Supervision of design teams: The instructor of the course will supervise the activities of each student design team and give advice when requested.

Design process: The following steps of Technology Education Design Process will be used throughout the entire research and design process:

- ❑ Defining a Problem.
- ❑ Brainstorming.

- ❑ Researching and Generating Ideas.
- ❑ Identifying Criteria.
- ❑ Specifying Constraints
- ❑ Exploring Possibilities.
- ❑ Selecting an Approach and Develop a Design Proposal.

The other two design processes ("engineering design process" and "combined engineering and technology design process") can be used as well.

Storage structures (water tower and silo)


Signage structures (light house)


Transportation structures (suspension bridge)


Directing structure (tunnel)


Support structures (chair)

Figure 1 Construction Systems (source: http://images.google.com/).

Sheltering structures Crystal Cathedral, Orange County, California)

Sheltering structures (Colonial Revival house)

Sheltering structures (Victorian house)

Sheltering structures (Thai bamboo house)

Sheltering structures (Nordic energy saving house)

Figure 1 Continued (source: http://images.google.com/).

Sheltering structures (Xiamen University campus buildings, Anglo-Chinese style)

Sheltering structures (Irish cottage house)

Sheltering structures (Sidney Opera House)

Sheltering structures (Bird Nest or Beijing National Stadium. Principle design firm: Herzog & de Meuron of Switzland)

Sheltering structures (Korean Royal Palace)

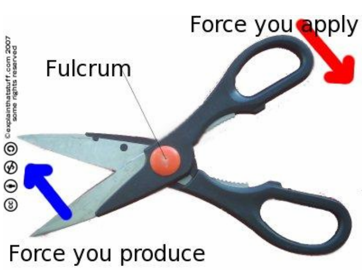
Sheltering structures (traditional German house)

Figure 1 Continued (source: http://images.google.com/).

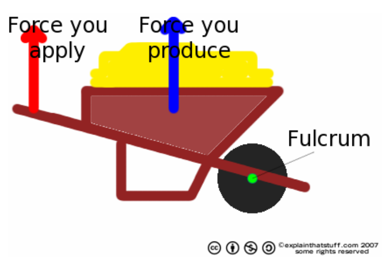
Sheltering structures (Mongolian yurt tent)

Defense structures (fortress and castle)

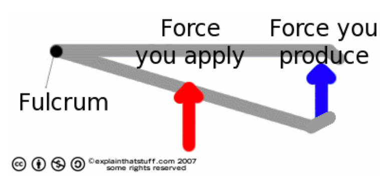
Figure 1 Continued (source: http://images.google.com/).



Class 1 lever (Scissors)



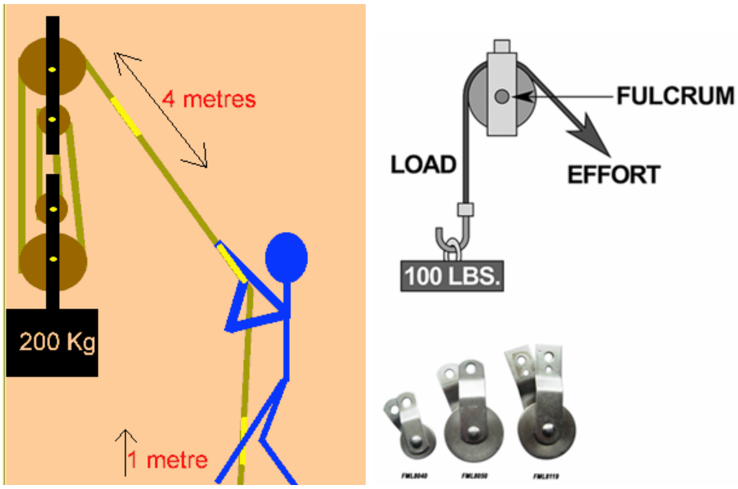
Class-2 lever (wheelbarrows)



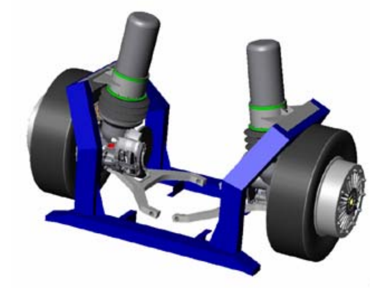
Class-3 lever (Tweezers)

(Source: ExplainThatStuff, 2008)

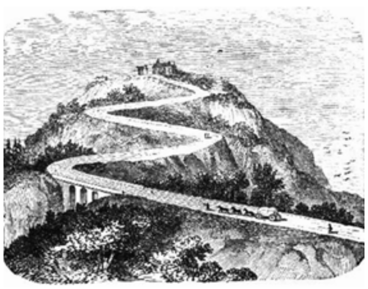
Figure 2 Mechanical System and Rube Goldberg Competition (source: http://images.google.com/).



Pulleys

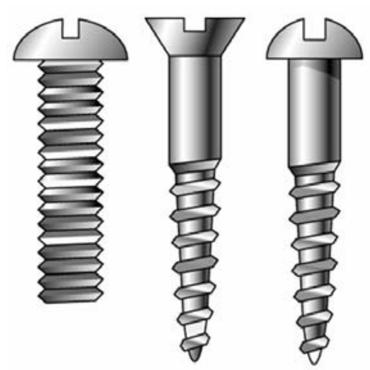


Wheel & Axle

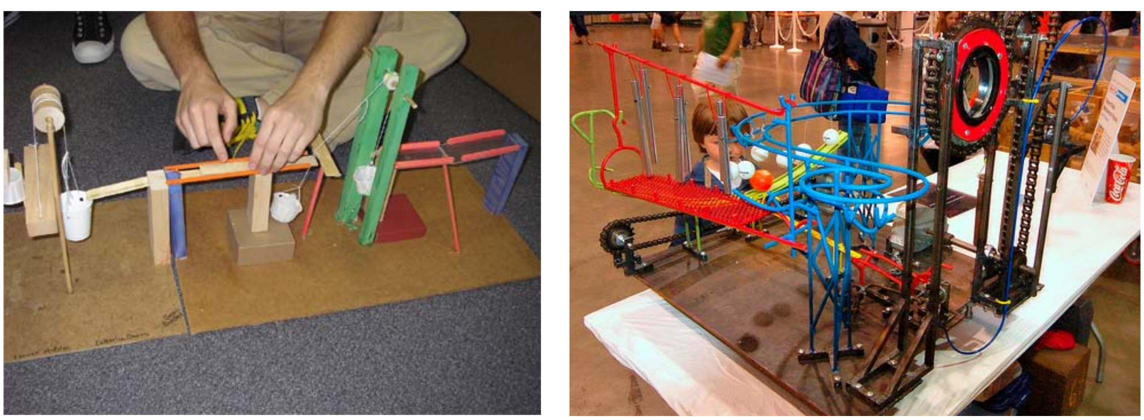


Inclined Plane

Wedge



Screw



Rube Goldberg Competition

Figure 2 Continued (source: http://images.google.com/).

Human-to-human (note taking)

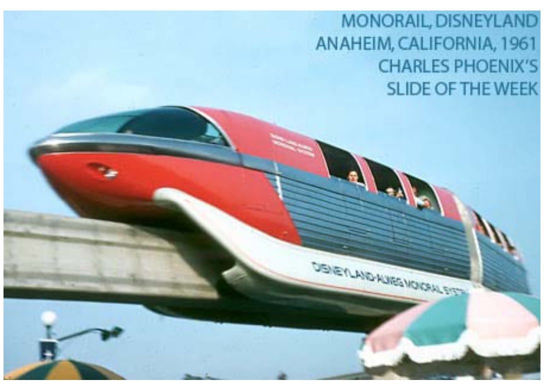
Human-to-machine (computer)

Machine-to-machine (thermostats)

Machine-to-human (alarm clock)

Supplementary (compass)

Figure 3 Communication System (source: http://images.google.com/).



Land transportation (monorail)

Water transportation (biodiesel speed boat)

Air transportation (helicopter)

Space transportation (space shuttle)

Figure 4 Transportation (source: http://images.google.com/).

<u>Introduction</u>:

In conducting this design activity, students will learn to solve an open-ended and creative conceptual design problem, using the time-tested instruments of design ideation such as brainstorming.

<u>“Brainstorming” concepts</u>: According to Wikipedia, the free encyclopedia (2009), “brainstorming” is a group creativity technique designed to stimulate and generate a large number of creative ideas for the solution to a problem, first popularized in the late 1930s by Alex Faickney Osborn in a book called *Applied Imagination*. There are four basic rules in brainstorming:

1. <u>Focus on quantity</u>: “Quantity breeds quality.” “The greater the number of ideas generated, the greater the chance of producing a radical and effective solution.”

2. <u>No criticism</u>: “Instead of immediately stating what might be wrong with an idea, the participants focus on extending or adding to it, reserving criticism for a later ‘critical stage’ of the process. By suspending judgment, one creates a supportive atmosphere where participants feel free to generate unusual ideas.”

3. <u>Unusual ideas are welcome</u>: “They may open new ways of thinking and provide better solutions than regular ideas. They can be generated by looking from another perspective or setting aside assumptions.”

4. <u>Combine and improve ideas</u>: “Good ideas can be combined to form a single very good idea, as suggested by the slogan ‘1+1=3.’ This approach is assumed to lead to better and more complete ideas than merely generating new ideas alone. It is believed to stimulate the building of ideas by a process of association.”

Before the start of this project, students should get more information on brainstorming, by reading thoroughly the article tiled *Brainstorming* on the website of Wikipedia, at http://en.wikipedia.org/wiki/Brainstorming.

"Brainstorming" Activities and timelines: In practice, "brainstorming" can be done by students working individually and as groups. There will be two categories of "brainstorming" activities for this project, with different time lines:

- For the overall creative conceptual design of the Engineering and Technology Theme Park: Student design teams will map out the general strategy for the Theme Park, before the 5th week of the semester.

- For particular parts of the design corresponding to any of the particular Themes explored during the course: Student design teams will complete the "brainstorming" sessions by the deadline each Theme is completed.

Students will use PowerPoint files supplied by the instructor as well as websites listed in the List of Reference Internet Websites for the Conceptual Design (Engineering and Technology Theme Park), at the end of this handout, as reference for the completion of all "brainstorming" sessions.

The following step-by-step procedure could be repeated many times over until a satisfactory final design solution is found:

1. Initiation: In the first group meeting, students will establish design criteria and discuss relevant issues (refer to the next section of this handout), and elect a group coordinator. This step should be completed within the first 3 weeks of the semester.

2. Rough individual brainstorming: Each student team member will generate at least 5 design ideas for creative and conceptual design of the Engineering and Technology Theme Park. This and subsequent steps will be completed throughout the whole semester.

3. Initial presentation and group evaluation: There will be 2 rounds of comparative evaluation and selection, based on the design criteria established in step 1 (Initiation):

   - Each student team member will present design ideas; the rest of group members will select the most desirable idea as well as desirable elements from other ideas; the presenting student will then incorporate these elements into the selected design idea, with a new sketch;

   - Each student member will present the new design idea one by one; all group members will then select the most desirable idea as well as desirable elements from other ideas for the whole group, and collectively integrate them into the "most realistic and creative design idea for the group."

4. Elaborate Individual brainstorming: Next, using the "most realistic and creative design idea for the group" established in the last step, each student team members will individually work on its various particular aspects.

5. Further group evaluation and brainstorming: Finally, each student team member will present his or her elaborate version of the "most realistic and creative design idea for the group;" all group members will next evaluate and compare the strengths and weaknesses of each version, and through the final round of collective brainstorming, the whole group will create the "Final Creative and Conceptual Design for Engineering and Technology Theme Park," on 17 in x 22 in paper, in ink, crayon and color pencils.

During the entire brainstorming session, students should record design ideas in engineering notebooks with notes, sketches (using pens, crayons and color pencils) and printout attachments.

The main issues to be addressed:

For the Conceptual Design (Engineering and Technology Theme Park):

Using "brainstorming" concepts to define the design problem, students are to answer the following questions:

1. Overall creative conceptual design strategy:

    - How to integrate various themes of science, engineering and technology in an interactive and harmonious way?
    - How can the Theme Park be both educational and entertaining? (Hint: Disney and science fiction style imageries could serve as a reference. Refer to *Figure 5*).
    - How can various forms of non-polluting and sustainable energy sources be used in the Theme Park, either for generating electrical power for the operation of the Theme Park, or for display and demonstration purposes? (For information on alternative energy, students could search thought the websites on the List of Reference Internet Websites for Alternative Energy. *Figure 6* and *Figure 7* illustrated some of the most used forms of solar and wind energy).

2. Design strategies for particular parts:

- How can different components of science, engineering and technology under various themes be discomposed, reassembled, and integrated into innovative new components? For example, the Anglo-Chinese style Xiamen University campus buildings (*Figure 1*) combined traditional Chinese style roofs with British style floors.

- How can different branches of science, engineering and technology be integrated into innovative new branches? How to integrate functional elements of life forms (humans, plants and animals) with mechanical, construction, communication and transportation systems? For example, bionics is the integration of life forms found in nature (such as the biological structure of birds and other animals), and mechanical or electronics engineering systems and modern technology, taking advantage of the fact that evolutionary pressure typically forces living organisms, including fauna and flora, to become highly optimized and efficient. The word is possibly formed from “biology + electronics.” Examples of bionics include the hulls of boats imitating the thick skin of dolphins; and robotics performing human like behaviors (*Figure 8*).

- How to harmonize many different aspect of the Theme Park with a common element? For example, for the design of innovative sheltering structures, we can use elements from Victorian style or Colonial Revival style houses (roof, windows, etc.) as a unifying elements to aesthetically link all building structures.

Figure 5 Disney and science fiction style imageries.

Parabolic dish used to produce solar power

Solar water heaters

Solar panels on rooftop

Solar powered aircraft

Figure 6 Typical application of solar energy (source: http://en.wikipedia.org/wiki/Solar_energy)

Small wind turbine

Large 5MW wind turbine towers

Figure 7 Wind energy (source: http://en.wikipedia.org/wiki/Wind_power)

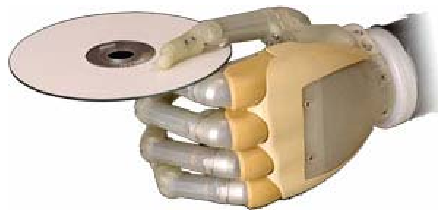


Figure 8 Bionics and robotics (source: Bionics http://images.google.com/).

For the Instruction Unit Development: Students are to apply the principles of "Analytic Reduction" to break down the instructional material into small units that can be covered in one class meeting at K-12 level, with appropriate integration of engineering design principles, concepts, formulas, exercise and review problems, and other necessary elements.

Learning Objectives:

The most important objectives of this design project include:

1. To learn how to apply the principles of "brainstorming" to stimulate creative conceptual design ideation, and to teach "brainstorming" techniques to kindergarten and elementary school pupils.

2. To learn and practice the basics of professional engineering sketch;

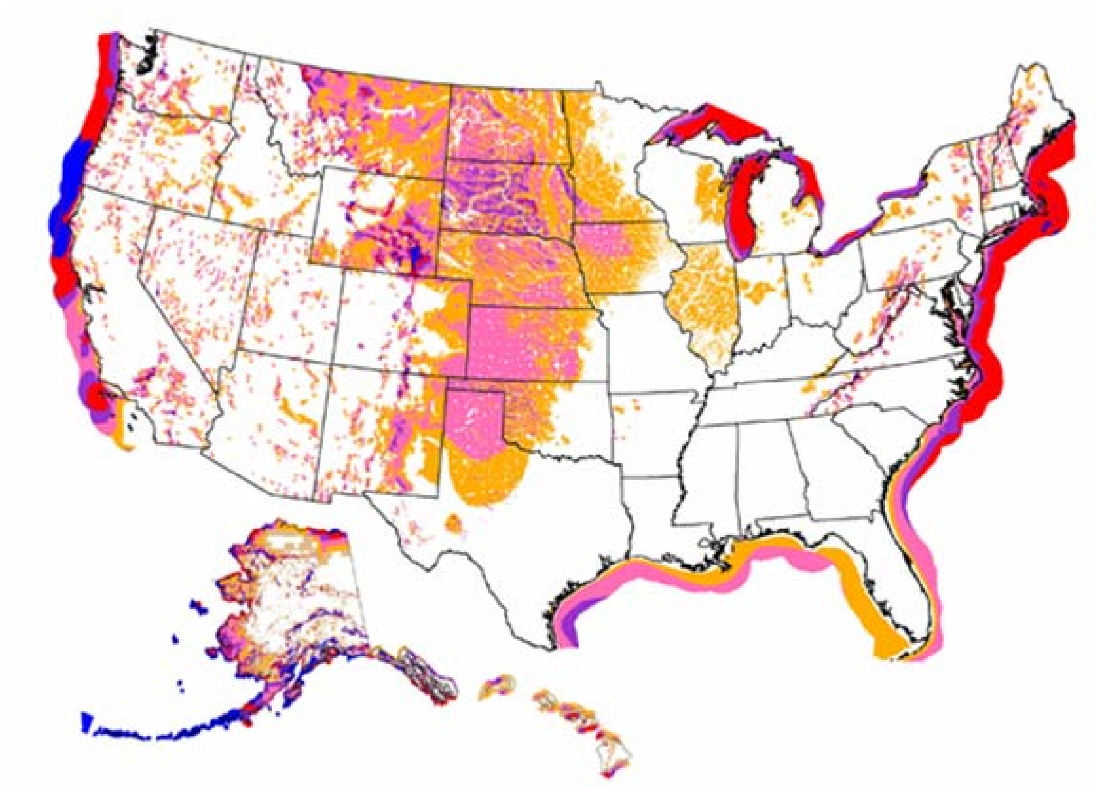
3. To learn how to search for relevant information on science, engineering and technology through the Internet.

Design Constraints:

This project is an exercise on stimulating creative concepts through "brainstorming;" rather than trying to complete a totally functional deign, the most important objective is to enhance the ability to imagine and to create and to achieve a conceptual design that might work. Students should keep their mind widely open so as to allow the free flow of innovative though. However, the following design constraints should apply:

1. The total dimensions of the Theme Park should not exceed the size of Disneyland in Orange County, California;

2. Preferably, the location of the Theme Park should be in an area with abundant sunlight, strong wind, and near a running river or an ocean, to generate sufficient amount of solar, wind, water and tidal power. For information on potential of generating wind power in different parts of the United States, study the U.S. Wind Resource Map at http://www.windpoweringamerica.gov/wind_maps_none.asp (*Figure 9*). For information on potential of generating solar energy in different parts of the United States, study the Solar Energy Generation Potential map at http://www.epa.gov/renewableenergyland/maps/pdfs/non_utility_pv_us.pdf (*Figure 10*).



Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m^2	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
7	Superb	800 - 1600	8.8 - 11.1	19.7 - 24.8

[a] Wind speeds are based on a Weibull k value of 2.0

Figure 10 U.S. Wind Resource Map.

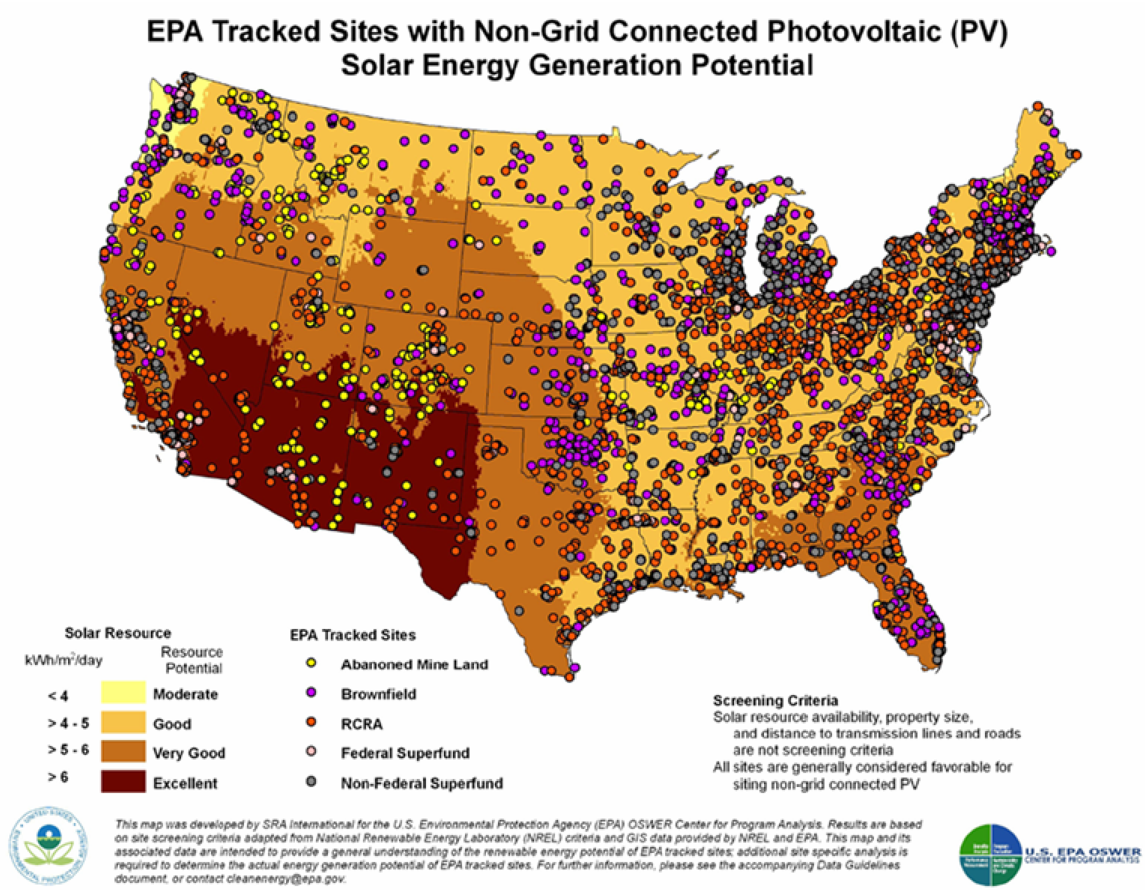


Figure 9 Solar Energy Generation Potential map.

Predictive Analysis:

Practically none.

Engineering design documentation:

The following documentations are required for both projects:

Engineering design progress log: The rotating Coordinator of each team will record the progress of each team member.

Engineering notebook: Throughout the entire design process, each team member will record all related activities with sketches, notes, and calculations, on engineering notebook, following the standards and conventions of its usage.

PowerPoint presentation: Each team will develop PowerPoint files and handouts for in-class presentations of the final design.

List of Reference Internet Websites for the Instruction Unit Development:

Eisenhower Model / K-12 Curriculum:
http://www.emich.edu/public/office_asl/Pages/Eisen.html

NASA science curriculum Science, Engineering, Mathematics and Aerospace Academy (SEMAA) - Grades K-12: http://www.nasa.gov/centers/glenn/education/SEMAA_GRC.html.

Free Online Curriculum for K-12: http://www.TryEngineering.org (Multi-language → http://www.tryengineering.org/home.php), and http://www.TeachEngineering.org

Boston Museum of Science: http://www.mos.org/EIE

Ford Partnership for Advanced Studies: http://www.FordPAS.org

Materials World Modules: http://www.materialsworldmodules.org

Play School: http://www.abc.net.au/children/play/

List of Reference Books and CDs for the Instruction Unit Development:

Benenson, G., & James L. Neujahr, J, L.. (2002). *Mechanism and Other Systems*. Portsmouth, NH: Heinemann. ISBN: 0-325-00468-4

Geoffrey C. Orsak, G. C., Wood, S. L., Douglas, S. C., Munson, D. C., Treichler, J. R., Athale, R. A., & Yoder, M. W. (2003). *Engineering our digital future: The infinity project*. Upper Saddle River, NJ: Pearson Prentice Hall. ISBN 0-13-184828-3

UGA. (n.d.). *Appropriate technology reference library CD collection.* University of Georgia Science Library.

List of Reference Internet Websites for the Conceptual Design (Engineering and Technology Theme Park):

1. For construction systems:

Wikipedia. (2009). *Construction*. From http://en.wikipedia.org/wiki/Construction

Wikipedia. (2009). *Architectural style*. From http://en.wikipedia.org/wiki/Architectural_style

2. For communication systems:

Wikipedia. (2009). *Communication*. From http://en.wikipedia.org/wiki/Communication

Wikipedia. (2009). *Digital communications*. From http://en.wikipedia.org/wiki/Digital_communication

3. For mechanical systems:

Wikipedia. (2009). *Machine*. From http://en.wikipedia.org/wiki/Machine

4. For transportation systems:

Wikipedia. (2009). *Transport*. From http://en.wikipedia.org/wiki/Transport

Wikipedia. (2009). *Vehicle*. From http://en.wikipedia.org/wiki/Vehicle

List of Reference Internet Websites for Alternative Energy:

Wikipedia. (2009). Alternative energy. From http://en.wikipedia.org/wiki/Alternative_energy

Wikipedia. (2009). *Renewable energy*. From http://en.wikipedia.org/wiki/Renewable_energy

Wikipedia. (2009). *Solar energy*. From http://en.wikipedia.org/wiki/Solar_energy

Wikipedia. (2009). *Wind power*. From http://en.wikipedia.org/wiki/Wind_power

List of Reference Internet Websites for bionics and robotics:

Wikipedia (2009). *Bionics*. From http://en.wikipedia.org/wiki/Bionics

Wikipedia (2009). *Robotics*. From http://en.wikipedia.org/wiki/Robotics

Reference

ExplainThatStuff. (2009). *Tools and machines*. From http://images.google.com/imgres?imgurl=http://www.explainthatstuff.com/scissors.jpg&imgrefurl=http://www.explainthatstuff.com/toolsmachines.html&usg=__tfNWWb6T0wIngH326-EsLEpHvwY=&h=296&w=400&sz=21&hl=en&start=93&tbnid=dLXdB1ZCA3r9iM:&tbnh=92&tbnw=124&prev=/images%3Fq%3Dlever%26start%3D84%26gbv%3D2%26ndsp%3D21%26hl%3Den%26sa%3DN)

Google.com. (2009). *Google images*. From http://images.google.com/

Wikipedia. (2009). *Brainstorming*. From http://en.wikipedia.org/wiki/Brainstorming