



Honorable Mention
The Research and Design Lab:
A Systematic Approach to Problem Solving
Andrew R. Myrick - South Burlington High School

Goal and Objectives:

Develop personalized, systematic approaches to problem solving.

Standards for Technological Literacy:

[International Technology Education Association](http://www.itea.org) (www.itea.org)

- ✓ Standard 8: Students will develop an understanding of the attributes of design.
- ✓ Standard 9: Students will develop an understanding of engineering design.
- ✓ Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.



Project Description:

The Research and Design Lab addresses the needs of students wishing to enter the engineering/design fields. Invention, methods of problem solving, and development of necessary content knowledge are presented as tools to solve to a problem. Students define and develop personalized models of problem solving to discover efficient solutions. Engineering Contests are used as a context. We have competed in the University of Vermont's DesignTASC competition (www.emba.uvm.edu/TASC), and as our program has expanded, participated in the West Point Bridge Design contest (bridgecontest.usma.edu), and the Boston University Engineering and Design Contest (www.bu.edu/eng/design).

Lesson Plans and Timeline:

Throwing problems at students is not teaching problem solving. Students participate in *Design Challenges* to construct solutions to problems. These problems are carefully designed to address specific National Standards related to problem solving, design, and tool use. These Design Challenges have been refined and field tested for five years.

- Design Challenge 1: Paper Towers
- Design Challenge 2: Paper clip equation
- Design Challenge 3: Electronic Research
- Design Challenge 4: Electricity and Electronics
- Design Challenge 5: Computer Aided Design
- Design Challenge 6: Computer Aided Manufacturing
- Design Challenge 7: Participation in an Engineering contest
- Design Challenge 8: Mapping your solution; How do you invent solutions?

Phases and Timeline:

Delivery of Design Challenges should be fast and furious at the beginning of the course. After the challenges are almost exhausted (save one or two for invigorating a class in the doldrums), introduce an Engineering contest. Although difficult to teach, students must take the responsibility to read and understand the rules and regulations. I often give them the assignment to build the competition are or “playing field.” At this point students need lots of time for trial and error, research, and practice. Mini-lessons on soldering, fasteners, tool safety, and Computer Aided Design keep students on task. Create an environment where students explore and experience, rather than follow assignments, and students will develop a great deal of self direction. Tailor lessons and assist in research in a student directed manor. More often than not, the teacher’s solution will not work as well as a student’s, as the students have more invested in their own ideas.

Equipment Required:

Most of the equipment is available in the general supply closet of any office. Paper, glue, paper clips, water bottles, etc. The trick is in the delivery.

Common tools and equipment:

- Hot Glue guns
- Foam core
- Recycled cardboard
- Recycled paper
- Soldering iron and related equipment
- Circuit breadboards
- X-acto Knives
- Hand drills
- Screwdrivers
- Fastener assortment
- Miscellaneous gears and shafts (available from used printers)
- Electric hobby motors (<http://www.radioshack.com>)

Specialty equipment:

- Bandsaw
- Drill press
- Computer controlled Milling Machine w/software (www.sherline.com)

Delivery of Design Challenges:

Students engage in the lessons, which progress rapidly from the simple to the complex. Students participate in the Challenges by themselves and with collaborative groups. These collaborative groups are self-chosen and/or teacher assigned. This is to give students an experience similar to the workplace, where they might not always work with their friends. Students learn to recognize the strengths and weaknesses of others, and to capitalize on their own strengths. These group challenges allow students to identify those traits necessary for successful problem solving.

Collaboration With Others:

Assign the first Challenge to groups of two randomly assigned students. Many students have never worked in this arrangement, and find it difficult at first. It encourages them to recognize other’s strengths and weaknesses, as well as builds their self esteem, confidence, and assertiveness.

Problem Solving:

The second and third Challenges, which are assigned to self chosen groups, are debriefed at the completion of the third Challenge. Focus on the following problem solving methods:

- Applying the scientific and other problem solving methods.
- Following other's solutions may lead you to the finish line, but behind the group who thought of the solution
- Recognizing when your first idea does not work, and when you should start over with another idea.
- Meeting Deadlines: The paper tower challenge should end before the class ends, with enough time to record a grade in a spreadsheet. If they have not completed, their grade is recorded as a 0. With the trust level increasing, even students who do not focus on grades feel the sting of a poor grade. Reinforce that the objective of this activity is to impress upon them the importance of finishing on time.

Decision making - Design Constraints and Compromises:

As the Engineering Contest moves closer, give the students gift certificates to Radio Shack or Pittsco supply. The cost is minimal. The money is not the point. I often give them a certificate for \$5 per group. You can afford this on a limited budget through partnerships with local business and recycling centers which allow one to peruse their surplus. The \$5 serves as a starting point. Although they often supplement this with their own cash, they treat this very seriously. They begin to realize that there are costs and compromises



associated with designing a solution to a problem. This is also a teachable moment for reading specifications in a catalog. There is a tremendous amount of free information and solutions within the pages of electronic and mechanical suppliers. Companies like Radio Shack, Digi-Key, and Grainger provide a great number of solutions through their publications.

Lesson Plans:

Design Challenge 1: Paper Towers

Name:

Measurement:

Research and Design Lab Application of Physical Property Potential of cellulose Fiber Building Materials (Paper Towers)

Materials:

- Colored Paper rectangle
- Clear tape

Time limit:

- This class period

Challenge:

- construct the highest self supporting structure. Measured at point farthest from tabletop after 10 seconds.

Design Challenge 2: Paper Clip Equation

Although deceptively difficult, this leads students to understand that the solution may not be so obvious.

Materials:

- Paper clips
- Meter stick
- Mass of clip: .9520 grams each

Maximize the following equation, where;

x= number of clips ($x \neq 0$)

l= length in centimeters when suspended

m= weight in grams

s= score

$$S = -x(l - 10) - m^3$$

Design Challenge 3: Electronic Research

Involve your local librarian, and introduce search engines. Address reliability and proper citation. Favorites include Google.com, Altavista.com, and Dogpile.com. Determine the answer to a difficult scientific question, and encourage students to race to the answer. The first team to email a properly cited answer to the teacher wins.

Design Challenge 4: Electricity and Electronics

These lessons may be taught without the students realizing they are being taught a lesson. Start with boxes on the lab tables containing a battery, a tiny electric motor, and a small propeller. While delivering a typical lesson, let the students “play” with them. The next day, add a switch, a meter, or a light bulb. To achieve higher levels of participation, hand out components to the less assertive students. This encourages them to experiment, and gives them “trading fodder”. As the days pass, invariably one can coach them to questions, which are answered to the whole class. Students are able to discover electrical measurements and characteristics including amperage, voltage, switching, and relays.

Design Challenge 5: Computer Aided Design

Computer Aided Design is recommended as preparation for the Research and Design class. Students who have completed the R&D course are also invited back as teaching assistants. These students then teach mini lessons on the basics of CAD.

Design Challenge 6: Computer Aided Manufacturing

A Sherline CNC milling machine, purchased through the sale of some of the older, outdated equipment in the lab provides a platform for teaching Cartesian coordinates and programming. Files may be exported from numerous CAD programs, and must be manipulated with machining skill and programming. Sherline's manuals are well written, and many students have followed the directions for manufacture of small parts.

Design Challenge 7: Participation in an Engineering contest

Students may search the WWW using Google, Altavista, or other search engines. Encourage the Boolean operators of "design" "engineering" and "contest". There are contests available for little or no cost throughout the United States, usually sponsored by a Trade Association or an engineering college or university. The popular television show Battlebots has established a contest to design and build a destructive robot, and is offering a curriculum to match.

Design Challenge 8: Mapping your solution; How do you solve problems?

The objective is to use technology of the WWW to demonstrate the steps they took to solve the problem. The pre-test below is administered before the objectives of the lesson are shared. I then introduce the project, and give them time to surf the solutions of former students. This gives me the time to correct their papers. Since their solutions are more important than the technology to convey the message, I feel a level playing field for technological skills is important. Based on the scores on the pre-test, students are awarded 3.5" disks. The higher the number of incorrect answers, the more disks they receive. These disks will be worth one point each on their final grade. They are also considered legal tender, so you can trade them to other people for technical advice or other assistance. It is tremendously rewarding, because most of the disks never change hands. Rather, the students with the biggest weakness often feel that they need the extra points, and become self-directed as to their learning. It creates enough of a head start to empower them into recording their problem solutions in WWW format. The other valuable part of this project is that by using Web pages (which can be built and viewed from 3.5" disks) students can model a true problem solving process which is not linear. The scientific method is a linear model. Students are able to see that we each use different models of problem solving, and many of them are not linear. Students often use pictures and captions, show their failures, and allow a reader to link to their successes.

In the interest of space conservation, the following answer key is provided. Answers should be removed before administration.

Name	Answer Key
HTML	HyperText Markup Language: Web sites consist of html files, which allow browsers to transform the files into the pictures, text, and backgrounds you see. Browser Translates html files into the presentation form you see “on the internet” Netscape Navigator, Internet Explorer, Opera
Search Engine	Searches the WWW, looking for html files, usegroups, etc. Altavista, AskJeeves, Excite, etc.
WWW	The World Wide Web: Includes the internet, telnet, gopher, Kermit. Used to access files, e-mail, listservs, etc.
Internet	Specifically, the part of the WWW that uses http (hypertext transfer protocol) which is the protocol that allows transfer of graphics hypertext, links, etc. The internet is a powerful research tool.
FTP	File Transfer Protocol: used to transfer files on the WWW. To publish a file on a server, you would use WsFTP95le or CuteFTP.
Text Editor	Used to manually edit html files: Notepad and Pico are examples.

Short Answer	Answer Key
Where does your page title appear while using a browser?	The top left part of your screen
What is a GUI?	Graphical User Interface (allows navigation without typing in text and instructions.
What is an example of a graphical browser?	Netscape Navigator, Internet Explorer, Opera
Where does your file name appear when you are using a browser?	At the end of your URL in the address bar of your browser
How would you name the file of a web page that contained a description of the results from an experiment?	Example: results.htm(l) 8.3naming convention, no spaces
What is (are) your e-mail address(es)?	Yours: jonesm@yourschool.k12.vt.us
Which of the following programs may be used to edit web pages? (Check any that apply) <ul style="list-style-type: none"> ➤ Microsoft Word ➤ FrontPage ➤ NetObjects Fusion ➤ DreamWeaver ➤ Netscape Composer ➤ Pico ➤ Notepad 	<ul style="list-style-type: none"> ➤ Microsoft Word: Use the save as HTML command to turn any Word document into a Internet File ➤ FrontPage: Common Program, the Express Version is free with a download of Internet Explorer, the full program is part of many Microsoft software packages. ➤ NetObjects Fusion: Great 30day free download, \$200 after that, awesome editor ➤ DreamWeaver: also available as a 30 day free offer, more complicated than Fusion ➤ Netscape Composer: The best free editor around, part of the full Netscape Communicator download. ➤ Pico: Used as the text based editor on linux and unix computers, if you know about this, you probably do a lot of web page work. ➤ Notepad: Available on any Windows based machine, handy for “on the fly” html editing.

Assessment Tools:

Engineering contests are extremely effective for student's self assessment.

The following rubric is used for the technical portion of Design Challenge 8: Mapping your solution: How do you solve problems?

Web Site Evaluation Rubric/Rating Scale

Click on the description to see examples of other student's work.

0	1	2	3	4	5	
1. Navigation						Score
Most links do not work. Links not related to page topic. Links not current:out of date.		Most links work. Not more than one error 404 message. Relation to topic not clear. Links somewhat current.		All links work. Links related to topic. Links current and up-to-date.		—
2. Resources						
Use of copyrighted work without permission		Most work by others cited or linked		Work by others cited on separate page.		—
3. HTML						
No added HTML. WYSIWIG editor used exclusively.		HTML added for frames, counter, or e-mail.		HTML added for frames, counter, and e-mail.		—
4. Format						
Single page format. No anchors or frames.		Frames format, links work within frames.		Pull down menus and frames used. New windows open for outside links.		—
5. Images						
No original graphics. Graphics not related to page topic.		Some original graphics. Some relation to topic.		All original graphics. All images related to topic.		—
6. Technical						
Slow load time: over 100k. Large image size. Lots of animations. No compression of .gifs or .jpegs.		Reasonable load time:80-100k. Medium sized images. Few animations. Some file compression used for .gifs and .jpegs.		Fast load time: less than 80k. Judicious use of images and animations. Fully compressed .gifs and .jpegs.		—
7. Text colors						
Choices blend or clash with background choices causing reading difficulty. Links and visited links not delineated.		Choices result in readability with background colors. Links and visited links discernable.		Choices complimentary to background colors. Links and visited links clear and noticeable.		—
8. Spelling/Grammar						
Misspelled words. Errors in word usage common. No message conveyed.		Few misspelled words. Few errors in word usage. Hazy message conveyed.		No misspelled words. No errors in word usage. Clear message conveyed.		—
						Total
						—

Results of the Project (benefits to the students, awards, recognitions):

The computer in our classroom was a prize in the UVM DesignTASC. Students often refer to their placement in these contests on their college applications. One of my students was chosen for a BF Goodrich school/work partnership, resulting in a \$10,000 scholarship and summer employment in the engineering field. Students have attended Stanford, Harvard, MIT, RIT, WPI, UVM, Northeastern, and worked for many local and national employers. The R&D Lab is often the subject of local press coverage. Many parents have become ambassadors for the program, as it reached out and “grabbed” their teenagers. These methods allow students to challenge themselves, rather than attempting to challenge them.

Contact Information:

Andrew R. Myrick
South Burlington High School
Research and Design Lab 139
550 Dorset Street
South Burlington, VT 05403
Phone: 802-652-7047
Fax: 802-652-7013
E-mail: amyrick@sbschools.net
URL: www.uvm.edu/~amyrick