Created by Sharon Jaeschke

Middle School ENGINEERING SERIES

Purpose: to introduce students to engineering careers through projects which involve designing, building, and creating things. The projects involve working in small groups, buying materials or using limited materials, naming and making projects aesthetically appealing, and competing against other class groups.

Time used: one engineering project is conducted each quarter between other units. Two to three days are used for each. The outline of each is given below.

First quarter: Paper Airplane Contest
- Day one: discussion on engineering & ISU engineering video
- Day two: receive teams and work on designing, buying materials and building plane
- Day three: hold contest (in gym) and do simulation in apple lab

Second quarter: Boat Challenge
- Day one: discuss contest, video, "Who are Engineers, You?"
- Day two: receive teams and work on designing, buying materials, and building boats
- Day three: hold contest using whirlpool

Third quarter: Rocket Car Contest
- Day one: discuss contest, video, "She's the Engineer"
- Days at home (2-3 weeks) to design and build car
- Day two: hold contest in gym

Fourth quarter: Tower building contest
- Day one: Guest speaker: engineer to discuss careers & building things for stability
- Day two: build towers & measure

End of year discussion: why did we have the engineering days???

Because you may not like math and science but if you like the things you can do with an engineering degree then hang in there and learn the subjects that will get you a degree so you can do what you like for a living!!!

Unit Title: Middle School Engineering

Subject Area: Middle School Mathematics (7th-8th grades)

Rationale: The goal of this unit is to help students become familiar with careers in which mathematics plays a big part. Engineering is one such career. At the middle school level, students are deciding whether they will want to take college bound coursework in high school. Mathematics courses seem very dispensible to students who do not want to pursue college careers. They can avoid ever taking an algebra course and still meet our high school math requirements.

Since we are rural school district, our students do not have the opportunity to meet anyone with professional careers outside of teaching and self-employed farmers and small business owners. This will give the students the opportunity to not only meet but to work with an engineer on a regular basis for an entire school year.

By collaborating with an active engineer from Hewlett-Packard on four construction projects and then participating in a class competition after each, the students will become more familiar with the field of engineering and hopefully become more motivated to excel in math. The project will also improve communication and problem solving skills.

Objectives: The student will be able to:
Recognize the construction needs of the problem.

Analyze possible solutions to the problem.

Select criteria and establish constraints such as containing costs.

Communicate with other team members and the consulting engineer throughout the design process.

Carry out a solution to create a product and test it.

Prepare a report involving formulas to compute the group score based on cost, performance, and creativity.

Prepare an analysis report for the instructor and consulting engineer.

Description of Activity: Each quarter, the students will be placed in a group of 2-3 students and asked to design and build something. The first quarter it is a paper airplane, the second: a styrofoam cup boat, third: a toothpick tower, and the fourth: a balloon-powered car.

At the beginning of the year each student will be paired with an engineer from Hewlitt-Packard and be given time from class bi-weekly to email the engineer with information and questions about how to best approach the project. (web site for the HP Mentor Program: http://mentor.external.hp.com) The students have access to their accounts daily at our school so they may communicate as much as they wish with the engineer.

At the end of each nine weeks, the groups will construct their project during classtime one day and compete in a contest against the other groups the next day. Then a final report will be prepared to arrive at a team score and each group will be asked to evaluate the team's performance. Each student will be expected to report to his/her engineer regarding the results of the contest.

TEAM SCORING SHEET

TEAM ONE

MATERIALS	COST

SPY CHECKMARKS: _____ _____ _____ _____

TOTAL POINTS: _____

TEAM TWO

MATERIALS	COST

SPY CHECKMARKS: _____ _____ _____ _____

TOTAL POINTS: _____

TEAM THREE

MATERIALS	COST

SPY CHECKMARKS: _____ _____ _____ _____

TOTAL POINTS: _____

TEAM FOUR

MATERIALS	COST

SPY CHECKMARKS: _____ _____ _____ _____

TOTAL POINTS: _____

TEAM FIVE

MATERIALS	COST

SPY CHECKMARKS: _____ _____ _____ _____

TOTAL POINTS: _____

TEAM SIX

MATERIALS	COST

SPY CHECKMARKS: _____ _____ _____ _____

TOTAL POINTS: _____

TEAM SEVEN

MATERIALS	COST

SPY CHECKMARKS: _____ _____ _____ _____

TOTAL POINTS: _____

TEAM EIGHT

MATERIALS	COST

SPY CHECKMARKS: _____ _____ _____ _____

TOTAL POINTS: _____

The Design Process

Identify Need Before the design process can begin, someone must recognize that constructive action needs to be initiated to improve a product, system, or situation.

Define the Problem Once a need has been identified, the actual problem must be clearly defined. If analysis begins before the problem is defined, it is possible to waste time and resources solving the wrong problem or a problem that no one is interested in.

Search for Information The type of problem usually dictates the types of data required to solve it. Information must be gathered to answer all types of questions about the problem and potential solutions. For example: What has been written about it? Is there a solution already on the market? What is wrong with the current process/product? What is right? Will consumers pay for a better solution? How much?

Select Criteria and Establish Constraints Certain characteristics of the solution are known even before alternative solutions are generated. These characteristics are in the form of criteria and constraints. Examples of desirable characteristics or criteria may include lower cost, lighter weight, and greater reliability. There will also be certain non desirable items, limits, or restrictions on the solution. These are the constraints and may include such things as size, weight, or cost limits which cannot be exceeded.

Generate Alternative Solutions A list of as many tentative solutions as possible should be made. Tools and activities such as check lists and brainstorming sessions are often used to stimulate thought processes and generate alternative solutions.

Analyze Solutions To determine the best solution in light of available knowledge and criteria, the alternative solutions must be analyzed to determine performance capability. This is usually done by weighting the criteria and constraints and ranking each alternative solution in each area. Some subjective analysis by the engineer(s) and/or design team is usually involved as well.

Make Decision To decide between several alternatives, as much information as possible about each is necessary. After each alternative has been evaluated against each criterion and constraint, and after other factors such as common sense and gut-feelings have been taken into account, one alternative should appear as the "best" solution.

Communication When the decision has been made, the solution must be communicated to designers in the form of written and graphical specifications so that production may begin and/or the correct changes may be made. Another type of communication involves explaining, persuading, and selling the solution to supervisors and customers.

The following definitions of various branches of engineering were written specifically for middle school students to give them an awareness of what engineers do.

AEROSPACE ENGINEERING

The aerospace engineer deals with all aspects of flight: flying at all speeds, in the air, in the water, and in many other environments. Aerospace engineers work with teams of other engineers designing and testing aircraft, missiles, space vehicles, helicopters, hydrofoil boats, ships, and underwater ocean vehicles. They may work to determine the best aerodynamic shape and wing size for an airplane or the effect of the airflow around a vehicle. Aerospace engineers may work with propulsion systems like turbo or fan jets, rockets, nuclear propulsion, and electric propulsion used in deep sea vehicles. They study mission planning as well as satellite orbits and spacecraft systems.

The aerospace engineer's job is to design aircraft that will make transportation more efficient. They design space vehicles that will improve communications and navigation and provide security for our nation.

AGRICULTURAL ENGINEERING

Agricultural engineers use their math and science backgrounds to design better systems for the farming industry. Agricultural engineers may work for companies that build farm equipment like tractors and combines. They help design this equipment so that crops can be grown and harvested with more efficiency and higher quality. They help find ways to improve soil conservation; for example, they may determine the best planting methods for farmers to use on different types of soil.

Agricultural engineers also work within the environments where farm animals live. They help design buildings and feeding systems for the animals. They may determine which system is best to control the temperature and humidity in a dairy barn, for example, to allow the animals to be comfortable and healthy.

Agricultural engineers help farmers and the farming industry provide more food (vegetables, grains, and meats) for our growing nation and world.

ELECTRICAL AND COMPUTER ENGINEERING

Electrical engineers and computer engineers design electrical systems that meet human needs for today and for the future in nearly every branch of technology.

They use their understanding of math and science to develop systems that generate power using water energy (from rivers and dams), solar energy and nuclear energy.

They design the tiny electronic circuits that operate the radio, radar, and navigation equipment in aircraft as well as other electronic components which are used in computers, stereo systems, automobiles, and robots.

INDUSTRIAL ENGINEERING

Industrial engineers work mainly in the manufacturing industry. They design systems that involve people, materials, and equipment. They determine the most efficient way to arrange and coordinate the people with the materials and the equipment so that they can produce the highest quality product in the shortest time at the lowest cost. One example of a system designed by an industrial engineer is the assembly line.

CIVIL ENGINEERING

Civil engineers plan, design, construct, and operate some of the largest products around. These products include bridges, dams, tunnels, football stadiums, and other large structures that must withstand millions of pounds of force from gravity, wind, people, and earthquakes.

Some civil engineers work to control pollution in our water, air, and soil.

Civil engineers are also involved in designing systems that transport people and things. They build highways, subway systems, and canals. They are even designing the transportation systems that we could use if cities were built on the moon.

CHEMICAL ENGINEERING

Chemical engineers use scientific knowledge and chemistry to design processes that produce thousands of useful materials including fuels, plastics, food products, and fertilizers.

Chemical engineers are working to help produce new types of fuel that will burn cleaner and more efficiently. They are devising systems to control pollution by trapping harmful pollutants before they spread into the air.

Chemical engineers are designing high strength plastics that are stronger but lighter than steel. These plastics are being used to make products such as automobiles. Automobiles built using the strong, light plastics get better gas mileage because they don't weigh as much and are safer and less expensive to drive.

Chemical engineers are also involved in searching for cures and methods of preventing cancer, AIDS, and other deadly diseases.

CONSTRUCTION ENGINEERING

Construction engineers help plan, organize, and supervise the construction of buildings, airports, roads, tunnels, and other structures.

Construction engineers are involved in estimating the cost of all the materials and labor needed to build the structure. They also estimate the amount of time it will take to complete the project (this is often many months or even years).

Construction engineers organize all the people who will be working on the project, like carpenters, bricklayers, and electricians. They make sure that all the materials such as cement, steel beams, wood, bricks, cable and wiring are ordered and scheduled to arrive on time.

Once all the people and materials are available, the construction engineer supervises the construction process to make sure that everything is completed on schedule, within the budget, and to the owner's specifications.

MECHANICAL ENGINEERING

Mechanical engineers design systems in many areas of technology. They are involved in machine design, from designing automobiles to developing remote control robots that will help in space exploration.

Mechanical engineers design the heating and cooling systems for all types of buildings. They also develop the refrigeration systems used in your refrigerators and freezers that keep milk cold and ice cream frozen.

Mechanical engineers work with power transfer and heat transfer to design systems that turn the sun's energy into power or heat.

AIRPLANE DESIGN CONTEST

Your job is to work as an aerospace engineer for the next two days. Your company has been contracted to design and build a model airplane. It is important to make it cost efficient (in other words, the less you spend, the better). It is also important that it make long trips (in other words, the further the better).

Below is the list of materials your company can "buy" to build your model. You may only use materials that are on this list.

Full sheet of paper	7 cents each	straws	5 cents ea.
Half sheet of paper	4 cents each	rubber bands	3 cents ea.
8 inches of tape	5 cents each	pennys	3 cents ea.
small paperclips	5 cents each	toothpicks	1 ¢
large paperclips	7 cents each		

***Materials must be purchased by these quantities (no quarter sheets...) and nothing may be returned once it is purchased.

Tonight you need to put together a proposal for your company. The proposal must list the materials and total cost of the model, and have a side and top view of your idea. When you arrive to class tomorrow, you will turn in your proposal with the others in your company as well as a completed company proposal and a model plane.

When you are hired to work in a company, you do NOT get to choose your co-workers. Thus you will be notified of who else works at your company tomorrow when you come in. How well you work together will be important in order to complete the work in class.

WHAT DO YOU DO TONIGHT? Fill out the proposal on the next page by yourself. You need to draw the model but you do not need to build it. You need to figure out the total cost.

WHAT DO YOU DO TOMORROW IN CLASS? When you come in you will receive the names of those in your company. You get together with those in your group, look over the proposals, and come up with one design. Each group will have a leader, recorder, and flyer assigned. Then you go to the "store" (Mrs. Jaeschke's table) and "buy" your materials. (Mrs. Jaeschke will write down what you have spent). By the end of the period you need

to have your model built and turned in to Mrs. Jaeschke, along with the proposal sheets for each person in the group. You are not eligible for the contest the next day unless Mrs. Jaeschke has your plane at the end of the period.

THEN WHAT ABOUT THE NEXT DAY? The next day we will have half the teams go to the lunchroom or gym to fly their planes and the other half go to the apple lab (if it is available) to use the program Paper Plane Pilot and fly planes designed by the computer. Each team member will have a chance to fly their model. The longest flight will be recorded. Your recorder will need to fill out contest result sheets which list the cost points and distance points. The winning team will receive 3 extra credits, second 2, third 1.

WHEN YOU ARE WORKING WITH YOUR COMPANY TOMORROW, YOU CANNOT TALK TO ANYONE IN ANY OTHER GROUP AT ALL. EACH TIME SOMEONE IS SEEN TALKING TO THOSE NOT IN THEIR COMPANY, THAT PERSON'S COMPANY WILL LOSE 10 SPY POINTS. THESE WILL BE SUBTRACTED FROM YOUR CONTEST POINTS THE NEXT DAY.

Team Objective: to build an airplane at a minimum cost which will fly further than any of those made by the competition.

Materials & costs:

Full sheet of paper	7 cents each
straws	5 cents each
Half sheet of paper	4 cents each
rubber bands	3 cents ea.
8 inches of tape	5 cents each
penneys	3 cents ea.
small paperclips	5 cents each
large paperclips	7 cents each

*Materials must be purchased by these quantities (no quarter sheets...) and nothing may be returned once it is purchased.

Points for scoring:

1. Cost

   We will use the formula: Points for cost = 100 - c to determine how many points you get based on what you buy. (c stands for cents) Notice if you buy nothing you get 1000 points. Of course you won't get any distance points then though. The less you purchase, the more points you get in this category.

2. Distance

   We will use the formula: Points for distance = 5 x d
   (d stands for distance to the nearest inch.)

Total points = cost points plus distance points

Competition

A designated team member will stand behind a line and send plane in flight. A tape measure will be used to measure distance to the nearest inch.

Awards:

First place team members: 3 extra credit points each
Second place team members: 2 extra credit points each
Third place team members: 1 extra credit point each

MODEL PLANE PROPOSAL

NAME_____

MATERIALS & COST: _____ _____

_____ _____

_____ _____

_____ _____

TOTAL COST OF PROPOSAL: _____

SIDE VIEW BELOW:

TOP VIEW BELOW:

Grp # _____

MODEL PLANE REPORTING SHEET

TEAM MEMBERS: LEADER: _____
RECORDER: _____
FLYER: _____

ITEMS & COST: _____ _____
_____ _____
_____ _____
_____ _____
TOTAL COST _____

COST POINTS: 100 - TOTAL COST = _____
DISTANCE POINTS(longest flight in feet) =

SUBTOTAL TEAM POINTS: _____

(LEAVE THE REST OF THE FOR MRS. JAESCHKE TO FILL OUT)

MINUS SPY POINTS: _____
PLUS ANY PROPOSAL BONUS POINTS: _____

TOTAL TEAM POINTS: _____

TEAM FINISH PLACE

THE BOAT CHALLENGE

The Challenge: to build a boat that is low in cost, performs well, looks attractive, and is capable of carrying lots of weight.

Details: Each team of three will design a boat which consists of a styrofoam cup and other materials as listed. The purpose is to build a craft that will hold the predicted weight without sinking. Each team will need to give a load prediction (number of bolts your company "guarantees" your boat can safely carry). Additional points will also be given for total number of bolts the boat actually holds, and how creative the design is. (Boat names are going to help your creativity points.)

There will also be points given based on the depth of your boat when it contains your prediction. If the boat rides on top of the water it will need a lot more fuel to run than if it is down into the water. We will measure the depth in centimeters.

Each team will consist of a leader, recorder, and person who fills the boat during the contest. However, all members should be equally involved in the research, discussion, and consultation of engineers during the preparation for and building of the boat.

After the contest all members will help the recorder with the score sheet and submit a report to me and the consulting engineers in which the following questions should be answered:

1. Describe the performance of your boat as it was filled?
2. What happened when it sank - did it tip, break apart, etc.
3. List some strengths of the design you used.
4. List some weaknesses of the design you used and how you could have improved the boat.

Materials list:

styrofoam cup - one free of charge
popsickle sticks - 10 cents
rubber bands - 10 cents
tape - 20 cents
string - 25 cents
cardboard (12" by 12") - 50 cents
aluminum foil - 50 cents

fasteners - 5 cents
thumb tacks - 5 cents
balloons first one: 25 cents, each additional 75 cents
(no more than 4 balloons may be purchased by a team)

You may experiment with materials without buying them. On the day of the contest the materials used and cost of the entry will be verified prior to putting it in the water.

Your entry will be given a ranking of 1-10 (with 1 lowest, 10 highest) by the instructor in regard to creativity prior to the putting it into the water.

All team members will be responsible for checking the arithmetic used to determine the team's final score. Any team with errors in computing will have 50 points deducted from their score.

Judging Criteria

1. **Cost**

To find the points your group has earned under the cost category, use the cost formula below.

Cost Points = 400 - total cost

(Notice: you will earn points until you spend over $4.00 for materials. If you spend over $4.00 you will lose points on this category.)

2. **Predicted Load**

Each team will predict how many washers their craft will carry before sinking. Points will be awarded based on whether the boat holds the predicted number of washers. If your boat sinks before holding the predicted number of washers, you do not get points in this category.

Prediction Points = Number of Washers predicted times 10

3. **Performance Points**

The goal of each team is to build a boat that, when holding the predicted number of coins, holds the rim of the cup nearly level with the surface of the water. Thus, once the boat contains the predicted number of coins, (if it is still floating), we will measure how far below the surface of the water the bottom is. You do not get these points if your boat doesn't hold the predicted number of washers.

Performance Points = Depth below surface in cm times 20

4. **Creativity & Aesthetic Appeal**

Each team's product will be judged before being put in the water on a scale of 1 to 10 with 1 being the lowest, 10 the highest. Judging will be based on how creative the team was and how nice the boat looks.

Judging Points = Ranking times 12

5. **Spy Points**

Whenever a team member is observed talking to someone NOT on his or her team, a checkmark will be recorded on Mrs. Jaeschke's scoring sheet for that team.

Spy Points = Checkmarks times 10

TEAM NUMBER_____

Place in competition: _____

BOAT CHALLENGE - PROJECT SCORE

LEADER: _____

RECORDER :_____

FILLER:_____

Materials used: _____ costs: _____

_____ _____

_____ _____

_____ _____

_____ _____

Total cost: _____

Cost points: (400 - total cost) = _____ *

Prediction: Our boat will hold _____ bolts.

IF YOU BOAT HELD THE PREDICTION: Prediction points times 10 = _____*

Creativity and Looks points

Ranking given by instructor: _____ times 12 = _____*

Performance points

Number of bolts held before sinking: _____ times 5 = _____*

Centimeters under when holding the prediction _____ x 10 = _____*

E-mail point

Number of e-mails sent and received added_____ times 3 = _____*

Spy points

Points subtracted for spying on other teams:_____** (subtract this)

TOTAL POINTS FOR THIS TEAM: _____ (Add up the 6 lines with stars behind them and subtract the spy points (double star number).

Math error?? _____ If yes, 50 points subtracted: New total _____

ENGINEERING DAY: ROCKET CARS

The Challenge: to construct a car which is aesthetically appealing, is powered by a balloon, and travels farther than any other car entered in the competition.

The Contest

Each student will construct a car to be used in the competition. The car must be made out of ordinary household materials such as milk cartons or jugs, cardboard, corn dog sticks, etc. I will supply the balloons for the competition so everyone has the same size. The balloon could be held in with tape on the bottom. A basic design is diagramed below.

When do we build?

This competition is different in that part of it involves you finding the best materials to complete the task. For that reason you will construct the car outside of school and bring them for the competition. You may team up with other class members of your choice and share ideas but each person must have an entry. You do not have to worry about cost as in the other engineering days. Creativity and design is much more important.

The Competition will consist of you blowing up the balloon to the size you want, putting it in your car, and letting it go. We will measure how far it travels in inches across the mp room or gym floor. The competition will be held the day after the test for this chapter so you have approximately 2 weeks to build.

Awards: because everyone is on his/her own, we will award extra credit out to 9 places in each section. Top 3 will get 3 extra credits each, next 3 will get 2 extra credits each, and next 3 will get 1 extra credit each.

Follow-up: after the competition, each of you will be asked to analyze how you could have improved upon your design so be thinking about that.

name _____

ROCKET CARS CONTEST REPORTING SHEET

(This sheet must be completed for you to earn the homework points for this activity. Score will be based on quality of this report with 30 possible homework points.)

1. Draw top down and side views of your entry in the space below:

TOP VIEW SIDE VIEW

2. How far did your car travel in feet and inches? _____

3. Explain (using at least 5 complete sentences) why you chose each part you used for your car (wheels, body, axles, balloon size, any other parts)

_____

_____

_____

_____

_____

_____

4. Detail below changes you would make if you rebuilt your entry -base your comments on the winning cars in your class. (If your car won this section is optional) Again use at least 5 complete sentences.

_____

_____

_____

_____

(continue answer on back side)

ENGINEERING DAY - TOWER BUILDING CONTEST

THE CHALLENGE: to design and build the tallest free-standing tower using spaghetti and marshmallows. The tower must be able to hold one large marshmallow off the ground.

THE CONSTRAINTS:

1. Each team will be given five large marshmallows, fifty small marshmallows, fifty strands of spaghetti.
2. The tower must be built within the math period and will be measured when there is 5 minutes left to allow for clean-up time.
3. Each team will consist of two people. Part of the challenge will be to work with your partner and be able to collaborate.
4. The tower must hold one of the large marshmallows completely off the ground. The other four large marshmallows may be used in the construction process.
5. The tower will be measured perpendicularly from the floor to the highest point.
6. You will be given time to consult your engineer on the best ways to carry out this task..
7. After the contest you will be asked to submit a report to me and your consulting engineer which answered the following questions:
    a) How high was your tower?
    b) Were there any unexpected problems that came up during construction?
    c) What would you do differently if given the chance to repeat this exercise?

Team Objective: to build an airplane at a minimum cost which will fly further than any of those made by the competition.

Materials & costs:

Full sheet of paper	7 cents each
straws	5 cents each
Half sheet of paper	4 cents each
rubber bands	3 cents ea.
8 inches of tape	5 cents each
penneys	3 cents ea.
small paperclips	5 cents each
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Points for scoring:

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We will use the formula: Points for cost = 100 - c to determine how many points you get based on what you buy. (c stands for cents) Notice if you buy nothing you get 100 points. Of course you won't get any distance points then though. The less you purchase, the more points you get in this category.

2. Distance

We will use the formula: Points for distance = 5 x d
(d stands for distance to the nearest inch.)

Total points = cost points plus distance points

Competition

A designated team member will stand behind a line and send the plane in flight. A tape measure will be used to measure distance to the nearest inch. Each group will be allowed two flights, the longest one will be used.

Report: After the contest, each group will be asked to submit a report to the instructor in which the following questions should be addressed:

1. How did you arrive at the decision for our design?
2. How important was the pilot in your success?
3. What happened that your entry did well or did poorly?
4. What changes would you make if you built another plane?