Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
2004 Volume IV: Energy, Engines, and the Environment

Machines: Designing Form and Function

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Introduction

For my unit I would like students to learn about the properties of energy and how learning to harness energy has changed our lives profoundly. Using the steam engine as an example of harnessing energy, I would like students to create their own model of a boat with a simplified steam engine. Students will draw up blue prints, work through a series of models, determine how to increase efficiency, and finally address the aesthetics of the boat as a form. This unit will be appropriate for all students because it will teach them through a variety of learning styles, most specifically kinesthetic learning, It will enforce every day skills such as problem solving, creating and testing a hypothesis, measuring, analyzing data and applying the elements and principles of design.

I teach art at High School in the Community (HSC), a small urban magnet school. HSC is a unique teaching environment because we are a teacher run school. Each teacher plays an integral role in the operation of the school. We are all encouraged to create our own curriculum in alignment with both the Connecticut and New Haven teaching standards. I have a large amount of freedom designing my courses so I try to create courses which will engage my students, integrate with other subjects and relate to their lives personally.

Since HSC is a magnet school two-thirds of the students are from New Haven and are selected through a lottery process. The other third of our population are students from surrounding suburban areas who choose to come to HSC instead of attending their local public high school. This selection process creates an extremely diverse community of students from a variety of different backgrounds. Each individual brings an extremely different set of experiences with him or her, creating a wonderful and sometimes challenging classroom environment.

Along with a diverse population there is a staggering imbalance in their art knowledge. Some of the students have a strong art background, while others have not had art for over three years. This forces me to teach the basic elements and principles of design while also making them interesting to those students for whom they are review. My classes include students from ninth through twelfth grade. Students attending HSC are required to take one full credit of art (some combination of visual art and music). This requirement sends many students through my door and finding a way to reach them all and keep them interested is one of my favorite challenges.

In teaching high school it is imperative to teach through subjects that are interesting to your students. This can be challenging with art because they often have a very limited definition of art. Usually they associate art simply with "fine art", or art which is hung in a museum. One of my main goals is to help students create their own personal definition of art. Through this unit I would like to broaden students' idea of what art is and open their eyes to the world around them. Things in art reflect nature, but even more importantly everything they use has been designed by an artist, from the clothes they are wearing to the seat they are sitting in, right down to the buses they ride. I want to bring art to their level as it surrounds them.

This unit will be appropriate for all students because it will teach them through a variety of learning styles. It will enforce the everyday skills of problem solving, creating and testing a hypothesis, measuring and analyzing data and drawing conclusions. It will also help students prepare for their CAPT test through a lab done to determine which variables will make their boat faster.

Objectives

The New Haven curriculum has six standards. This unit will meet all six. They are as follows:

- Standard One: Communicate in Art Media Techniques and Processes. Students will learn to draft plans and create sculptural models.
- Standard Two: Principles of Visual Organization, Structure and Function. Students will design the aesthetics and functions of a boat using the elements and principles of design.
- Standard Three: Evaluation, Critique and Integrate Art Concepts. Students will create numerous drafts of their boat. Each draft will be evaluated and critiqued, and the final boat will be a culmination of the best parts of each.
- Standard Four: Historical and Cultural Relationships and Influences. Students will look at the history of boats and the effect the steam engine had on the world.
- Standard Five: Critique and Assessment of Artwork. Students will complete a lab documenting the progress they make in boat building. Peer and self-assessment will also occur.
- Standard Six: Interdisciplinary Art Connections, Cultural and Historical Correlations. Students will make connections with science (energy), math (proportions and scale) and history (industrial revolution).

What is Art?

One of my main objectives for this unit is to have students wrestle with the idea “What is art?” in order to create their own definition of art. I will begin this unit by brainstorming with the class “What is art?” Through leading questions I would like students to begin to realize that even in the art room there are pieces of art besides simply what is hung on the walls. I would like them to start considering the utilitarian objects as well: chairs, tables, lights, etc. I would like students to start thinking about whether or not these objects can also be considered artwork.

From this discussion I would like students to begin thinking about how an industrial designer works. Though everyday objects serve a specific purpose they have gone through many stages of planning. Initially things were designed by an engineer to be sure the mechanics of the object worked correctly. After that an artist would design the aesthetics, or outward appearance, of the machine. Often times now these two people will work very closely with one another, making sure that form and function fit hand in hand. In some companies there is one person who does both of these jobs, called an industrial designer. The industrial designer will tackle both the aesthetics and engineering of the machine. By using simple objects around the art room, such as chairs and staplers, students will be lead through a discussion about the process which an industrial designer would go through to create these objects. Where do they start? What things are important for them to keep in mind? It is important for the designer to know as much as possible about the product they are creating.

- Who will use the product?
- What does it need to do (its main use)?
- How can it be made as efficient as possible?
- How can it be made aesthetically pleasing?

Throughout this unit students will be given the opportunity to become industrial designers. Students will learn as much as they can about boats and will then be challenged to put their knowledge to the test by creating their very own functioning model of a boat. To start students must learn as absorb as much information as possible about boats. The first two assignments are to help students increase their knowledge of different uses of boats throughout history and the aesthetics of boats.

History of Boats

Each student will be assigned a report on a specific type of boat. Students will draw types of boats from a hat. They will be expected to report on the history of their boat: who used it, what it was used for, its shape and any decoration the boat may have had. Students should also begin thinking about how the boats use energy and the efficiency of their boat. Below is a brief history of boats from which report topics may be chosen.

The first models of boats were canoes carved out of one solid piece of wood. These boats were quite heavy and took a long time to build. Canoes had two possible sources of energy. The first was the current of the body of water around them. If the current was moving quickly, the boat would also move quickly, however this source of energy was very unreliable. The second source of energy was manpower through paddling. This source of energy was obviously more reliable because men could judge how long and with how much force they could paddle to move the boat along.

Eskimos created boats of a similar style. They created a simple wooden frame and stretched animal skin over it. Other cultures used this same wooden frame and covered it with bark. This made the boats lighter and therefore they took less energy to power because men, wind, or current could move them more easily through the water. All of these boats used sap or pegs to keep the pieces together.

Romans and Greeks created boats which are similar to those we use today. This construction is called carvel planking. The keel is a piece of wood that runs up the center of the boat and serves as the backbone. U shaped pieces come out from the keel called ribs. These give the boat its form. Boards are then nailed or pegged to the ribs lengthwise along the boat. Caulk is used to fill in the holes between each of the planks.

These boats were used until about two hundred years ago when man began manufacturing flat boards and nails. Flatiron skiffs became the boat of choice. They were much easier to build because they could be quickly assembled and do not require a form to build around like carvel planking boats. Large sheets of cheap wood are curved and cut to create each side and the top. This is similar to the initial shape of our steam engine. Our boat will have curved sides and a flat bottom similar to the construction of a flatiron boat. Still these boats are all powered by man or wind through paddles or sails. (Michalak 9-14) They are extremely different from the boats powered by engines that we have today.

The above is a brief history of the progression of the boat, leading up to the production of the steam engine. The following are boats which students might choose from: canoe, kayak, Viking, powerboat, jet ski, pontoon, rowboat, powerboat, inflatable boat, army boat, emergency boat, fishing boat, yacht, cruise boat, ferry, oil rig, sailboat, raft, paddleboat, etc.

Part One: Comparing Boats through Observation

While students are researching a variety of boats they will begin to observe different types of boats from an aesthetic perspective as well.

Main Ideas

- Introduce students to the concept of machines, specifically boats, through close observation.
- Introduce the idea of improving upon an invention.
- Predicting changes which improvements on the boat might cause.

Objectives

- Observe two different boats in action from several angles.
- Identify, compare and contrast the energy source of each boat.
- Show how the parts in a machine relate to and affect each other.
- Predict changes which occurred from this improvement to boats.
- Create a detailed drawing of each boat, trying to label the parts.

Time

- Seven classes of 50 minutes.

Materials

- DaVinci machine drawings
- Teacher Exemplars, including breakdown of shapes
- Diagrams of other machines
- Paper
- Pencils
- Erasers
- Canoes with Rowers (wind-up)
- Putt-putt boats
- Sailboats

Day One

- Have students break into small groups.

- Examine boat in detail, look at parts.

- Have students discuss:

- What is a machine?

- What is the function of the boat?

- Where does the energy come from?

- What parts move?

- How do the parts affect each other?

- Draw the machine at rest, including as much information as possible.

- Teacher should show student how to break down boats into shapes to draw.

- Teacher should encourage drawing “cut away” views to see what’s going on inside.

Day Two and Three

- Repeat above for other two boats.

Day Four

- Have students compare and contrast the two boats they’ve studied.

- How are they different aesthetically?

- How are their functions different?

- How are their parts different?

- How do they use energy differently?

- What is their source of power?

- Which would you rather own and why?

- How would life be different if you had one instead of the other?

- Create a compare and contrast chart.

- Create a K-W-L chart for how boats work.

Day Five

- Review what students want to know about how boats work.

- Have students draw conclusions about work, energy and machines.

- What is work?

- How can you tell who is doing work?

- What is a machine?

Day Six and Seven

- Use the canoe to explain work, energy and systems.

- Include smaller demonstrations to illustrate points.

From these lessons students will learn drawing through observation. The teacher will demonstrate how to break down each boat into different shapes, how to use a basic unit of measure to ensure correct proportions, how to draw different shapes at different angles and how to draw symmetrical shapes.

Once students have created drawings from a variety of viewpoints of each of the three model boats (sailboat, putt putt boat and canoe) students will begin exploring how each of these boats works starting with the canoe.

How Does a Canoe Work?

Canoes are made out of a variety of materials such as steel, aluminum, wood, fiberglass and even plastic. The best material depends on where and how the boat will be used. A canoe for white water canoeing will be designed very differently than one which will be used on calm lakes for fishing. First we will look at the canoe without a rower. A canoe is the simplest of boat forms - a basic hollowed out hull with benches as seating. We are primarily concerned with the form of the hull. I would like students to consider which variables (things that can be changed) affect the speed of the boat? Simply by looking at the construction of the hull how could you change the speed of the boat?

- Materials
- Weight
- Shape
- Texture
- Symmetry

When the hull of the boat comes into contact with the water, water molecules become stuck to the hull from friction. This friction with the water is what slows the boat down. There are two ways to lessen the amount of friction. First is to lower the amount of surface area touching the water. The less area touching water, the less friction, and the faster the boat will move. (This is why many speed boats “plane out”; once they are moving at higher speeds much of the hull is out of the water so the boat can move much more quickly.) The second is by designing the hull so that water can easily move around it. The film of water molecules stuck to the hull from friction builds and thickens until it reaches the stern where it breaks. This is why the boat appears to be cutting through the water. (Winters, as the water passes)

Students will be challenged to choose from a variety of hull types, materials, textures, etc. to design the fastest boat. Students will create a hypothesis predicting which combination of materials, textures, shapes and design will create the fastest canoe. Students will create plans for their canoe learning important boat terminology. They will then build the plan they think will create the fastest boat and we will race the boats to see which variables make the largest difference.

Designing a Canoe

Student will predict which combination of variables they feel will create the fastest boat. They will then create blue prints for their canoe, just as a designer would. When designing a boat there are three important views that a designer uses: a profile (side) view, a plan (bird’s eye) view, and a section (slice perpendicular to the profile) view. Each of these views provides important information about the structure of the boat. Students will be creating their own plans for the simple hull of a boat. While creating these plans students will learn about ratios and proportions and drawing plans to scale.

The profile view allows the architect to look at the boat as it will float in the water. Usually a water line will be included in these drawings to signify how much of the boat will be submerged. The plan will show the layout of the boat from a bird’s eye view, similar to blue prints of a house. It will show the deck, any rooms and storage compartments. Lastly, sections show what a slice of the boat would look like. Many section plans may be made depending on the size and shape of the vessel. (Fig. 1)

The following vocabulary will be important when drawing their plans:

Chine - where the bottom and sides of the boat meet

Deadrise - the angle a hull bottom makes with a horizontal plane (helps cut through waves, etc.)

Freeboard - Distance from top of deck to water’s surface (varies with speed, and can also be different from the front of the boat to the back)

Keel - points along the bottom of the boat to provide stability

Part Two: Building the Fastest Canoe

Main Idea

Through examination of instructions students will understand the importance of clear planning. They will create a set of plans which they will use to create a canoe.

Objectives

- Review sets of instructions and determine what makes them successful.
- Identify and define the different parts of a boat.
- Create a profile, plan and section view of their canoe in scale.
- Indicate movement and energy flow correctly.

Time

- Ten days of 50 minutes.

Day One

- Students will discuss which visual instructions are most successful and why.
- What do *good* diagrams include?
- What information is most helpful?
- How much detail is necessary?
- Is there a legend?
- Students will note which ideas may be helpful in building their plans.

Day Two

- Discuss which views of a boat would be important to create.
- How can you tell what each side looks like?
- How do the different plans line up?
- How can you tell what is inside?
- Learn the terminology of boats.
- Introduction to form through hull shape.

Day Three - Five

- Discuss proportion.
- Who uses proportion?
- What happens if your proportions are wrong?
- Determine scale of graph paper.
- Create three different views of plans for their canoe.
- Teacher should show them a variety of hull plans.

Day Six - Nine

- Create a boat from their plans.
- What materials would work?
- What factors are important when building?

Day Ten

- Race boats to determine which plans are fastest
- Why did some boats go faster than others?

- What could you change about your boat to improve its speed?

Power in the Hull

The simple hull shapes which students have explored are reliant on only the current for their speed. The current of water is a constantly varying force which does not provide consistent results, so we add paddlers. The paddlers use oars to help them move the boat forward. By applying force against the water the boat is propelled forward. This is due to Newton's first law that every action has an equal and opposite reaction. While the paddlers are pushing backwards through the water, the boat is moving forwards. (Fig. 2) Although current and strength of the paddlers still play a large role in the speed of the boat, just adding the paddlers provides a much more reliable source of power. (Gillen, The Straight Shaft Paddle)

How Does a Sailboat Work?

Next we will compare the canoe to the sailboat. The design of the hull and the current of the water still have an effect on the sailboat, however the biggest difference is its power source: wind. Using sails to employ the force of the wind to propel the boat forward, there is far less reliance on human muscle power on these boats. If the wind is coming from behind the boat then it gets caught in the sails which push against the air similar to the way the paddles pushed against the water, propelling the boat forwards. However, if the wind is coming from another direction then Bernoulli's principle comes into play. Each sail is curved in such a way that when air molecules meet the sail they split and part of the air travels around one side of the sail, while part travels around the other side. What makes the sail work is that one side of the sail is curved, creating a longer distance for air to travel over. The air which travels over the longer distance does so in the same amount of time it takes the air to travel over the shorter distance, meaning that the air molecules are more spread out on the longer side. Because of this the more dense air tries to move towards the area where the less dense air is, pushing the boat forwards. (Fig. 3) Airplane wings work on the same principle. (Anderson, Newton's Laws and Lift) Because the boat relies more on wind power and less on human strength it can often travel much faster than a canoe, however if there is no wind at all it may be very difficult to get where you are going.

Renewable Energy

Both of the boats we just looked at use forms of renewable energy. Renewable energy comes from an energy source which will never be depleted. Fuels like oil and gas which we use everyday will eventually run out, where renewable energy sources are always there. In many places there is always wind, and rivers will always have currents because of the way they flow. Right now large amounts of our energy come from nonrenewable sources which will eventually run out, as our use of energy increases. Nonrenewable sources of energy also have harsh, lasting effects on the environment, from pollution to contributing to the greenhouse effect. Although they are more reliable than renewable sources of energy it is important that we begin to find other ways of harnessing energy. (What is renewable energy)

Nonrenewable Energy: The Steam Engine

After determining how the canoe and sailboat work students will be challenged to determine how the putt putt boat works. Students will be given materials to do a few smaller experiments relating to these principles.

What is the source of energy?

The putt putt boat does not have a rower like the canoe did, so where is the energy coming from? The energy is coming from the wax in the candle which is burning and providing heat to do work.

How is the heat doing work?

In order to understand the way our small model will work, students must understand phase changes. A phase change occurs when the molecules in one object reach a specific temperature which causes the molecules to change form. Phase changes go from solid to liquid to gas, or in reverse. Let’s take water, which when frozen is ice. If ice is heated to 32 degrees F then the molecules begin moving more quickly and they spread out, creating a liquid, or water. If water is then boiled at 212 degrees F the molecules begin to move even faster and the water will vaporize into steam, a gas. It is important that students understand these phase changes because our boat will be running because of the phase changes of water. The water in the metal piece is heated by the candle, and then it expands and becomes water vapor, a gas.

How does the phase change move the boat?

For our boat to work it will also be important that students understand that liquid and gas both travel from areas of high pressure to areas of low pressure. This can be demonstrated in a variety of ways to students. The air rushing out of a blown up balloon would be one, hot water rising to the top would be another (add food coloring to the hot water to show the obvious movement). The whole principle of our boat is that the heated water vapor must expand and then takes the path of least resistance to an area of lower pressure. The force of this steam moving out of the area of high pressure and into the area of water, low pressure, is what propels the boat forwards. (Fig. 4) Our small model is a simplified example of how a steam engine works. The invention of the steam engine revolutionized travel and communication.

History of the Steam Engine

The invention of the steam engine began back in the first century A.D. A Greek philosopher named Hero created an ‘aeolipile’ which worked on the same principle as a turbine; however Hero did not realize its potential to do work. His ‘aeolipile’ was a sphere which had two L shaped tubes on opposite sides of the sphere leading out of it in opposite directions. The sphere was filled with water, and then the water was heated. As the air above the water expanded it was forced out the tubes. Because of the positioning of the tubes the steam caused the ‘aeolipile’ to rotate (Fig. 5). Hero had discovered how to use heat to do work, however he did not realize it. (Storer 25)

Initially the steam engine was used to create a pump which would pump water out of mines. The engine used the principle of Hero’s ‘aeolipile’ to move water. Thomas Savery was the first to produce this type of pump. “In 1698 he patented his ‘engine’ for raising water ‘by the Impellent Force of Fire’” (Storer 35). The pump created a vacuum through the heating and cooling of air which caused the excess water to be sucked up and out of the mine shaft.

Another scientist named Newcomen used the same technology to move a piston which in turn moved a large wooden beam which moved the pump to pump out water (Storer 41). The next improvements came from James Watt who cut down drastically on the amount of water which needed to be heated, therefore reducing the amount of heat needed and increasing the efficiency. (Storer 52) It was not until later that the engines were used on machines for transportation.

Building Your Own Boat

Now that students have a better understanding of what makes different types of boats work, how the hull of a boat is designed, how to create plans for a boat and what materials work best they will begin to design their own boat.

Looking back to the process of an industrial designer, students must first choose what type of boat they would like to build and determine what characteristics will be important for it to be successful. We will review the different types of boats presented earlier through reports. Once students have chosen a purpose for their boat they must begin to think about the characteristics of seaworthiness, range, speed and comfort. They will need to assess the importance of each for their boat, and how they will accomplish each. Students will complete a rubric rating how important each of these factors is for their boat, and then in the end their boat will be tested for each through a series of tests testing speed, seaworthiness and comfort.

Seaworthiness

Seaworthiness speaks to the efficiency of a boat - how well is it designed for its intended use? The builder must think about what type of conditions the boat will be used it, and design towards those. If a boat is going to be used for fishing on a calm lake it will not need the same properties as a larger boat which will be out in the ocean. (Marshall 7) Deciding on the boat’s use will be the students’ first step. Thinking back to their previous experiments with hull size and shape they will need to decide what shape to make their boat and why. Seaworthiness will be assessed by recreating an environment similar to the one the boat would be used in (calm lake, wave pool as ocean, etc.)

Range and Speed

The importance of speed also depends on the intended use of the boat and is usually a consideration. Range means how far the boat will go on one tank of gas. Fuel efficiency is determined by many factors including the design of the hull, the weight of the boat, etc. Range and speed will be assessed by how efficient the boat is through an efficiency lab.

Comfort

Comfort covers a broad spectrum of ideas in reference to a boat. Comfort can refer to the comfort of the crew and passengers in terms of how the boat is constructed. The more room there is to move about the more comfortable the passengers will be. Added amenities and luxuries can also make your boat more comfortable. However, comfort can also refer to how comfortable you feel with your boat's abilities. It will be a much more enjoyable ride if you trust that your boat will be able to handle the weather, will provide a calm stable ride and will not have any problems traveling at the speeds it will be going. Comfort is all about luxury and being confident in your boat's abilities. (Marshall 72) Comfort will be assessed on how creatively students have manipulated the space to include storage, living space, cargo area and other needs which are important to their specific boat.

Part Three: Efficiency Lab

Students will create their first boat strictly following the instructions from the website. Once students have completed their first boat and understand how it works they will begin planning their final boat. Their final boat should be tailored to its specific purpose and should be as efficient as they can make it.

What is efficiency?

Efficiency is the amount of work being done by your fuel versus the amount of work it can do. Every type of fuel has a maximum capacity of work it can achieve. When designing engines, the goal is to get as close to this maximum capacity as possible. There are a variety of reasons that the maximum efficiency of a fuel might not be reached. For instance, our fuel for our boat is wax. When the wax is burned, some energy is wasted as heat, and some energy is wasted producing soot. Therefore because of our choice of fuel our boat automatically has some limitations on its efficiency. To measure their boat's efficiency students will measure the how far the boat goes and how long it takes to get there, using one "tank of gas" (completely filling the soda can piece with water). Once they have these two numbers determined they will be challenged to find ways to make their boat go farther and faster on the same amount of "gas". All of this data will be recorded and analyzed in a format similar to the CAPT test as an enrichment to the science curriculum.

Main Ideas:

- Understand the planning and process that goes into creating a machine.
- Understand the importance of improving a product.
- Looking at the boat as a form of art as well as a means of transportation.

Objectives:

- Create a functioning putt putt boat, and then determine how it can be altered to improve upon its performance and efficiency.
- Create three plans to scale for each view of their boat
- Consider the use of their boat and how they can best use the space.
- Determine what materials and shapes work best.
- Use elements and principles of design to enhance the appearance of their boat.

Time:

- Twenty Classes of 50 minutes.

Materials:

- see list on website

Week One:

- Constructing bare bones putt putt boat.

Week Two:

- Researching what type of boat they'd like to create and noting its important features.

Week Three:

- Creating prototypes to determine how they can increase the speed and efficiency of their boat.

Week
Four:

- Putting the final touches on their boat.

Aesthetics of a Boat

Students will explore line, color, balance and form which will enhance their boat. Depending on the function of their boat they will want the boat to have a specific appearance.

Line

Line is one of the easiest elements to use to create a feeling of motion. Horizontal lines give a sense of calm, vertical lines of stability and diagonal lines of motion. After learning about these properties of line students must decide which property is most important to their boat and add lines accordingly.

Form

There are two main types of forms: geometric and organic. Geometric forms are perfect forms such as circles, squares, triangles. Organic forms have a much more natural shape to them such as fruits, bones and nuts. Boats are composed mostly of geometric forms; however organic forms are usually more pleasing to the eye. Students will need to find a way to incorporate some type of organic form into their boat for interest and contrast.

Color

Specific colors bring about very different emotions in people. Depending on the purpose of the students' boats color choice will be extremely important. If they are working on a military boat, then camouflage will be appropriate. However, if they are working on a speed boat they might want to consider more warm colors like oranges and reds.

Balance

As mentioned before, balance is important for your boat to be comfortable; however it is also an important factor in your boat being aesthetically pleasing. If you have designed your boat so that it looks heavy in the front it will not be attractive, and by nature travelers will be weary of boarding. Would you want to ride on a boat which looked like its front might sink? Symmetry and asymmetry are important ideas when creating balance. Symmetry is when one side of an object is a mirror image of the other side. Symmetry is a very simple way of creating balance; however it is not very interesting. Asymmetry is when one side does not mirror the other. Creating balance using asymmetry is much more difficult than with symmetry. Students will be required to create balance using asymmetry.

Unity

Unity means that the boat looks like the whole thing was designed at once; it is not a boat which has been pieced together. It will be important for students to design their entire boat at once, without giving attention only to particular parts. It will be important for the boat to look like a whole, not like pieces were designed and then assembled as an afterthought.

Assessment

Students will be assessed at various stages throughout the boatbuilding process. They will be asked to give a presentation with a drawn visual representation of the boat they research. They will need to create hypothesis about what combination of variables will make the fastest canoe, and then test out their hypothesis. After that they will need to turn in a proposal for what type of boat they intend to build, including plans and specifics important to their specific boat. Their final grade will be based on all of these things, including their final boat. I would like to be able to put together a boat show for the rest of the school at the end of this process. I am also hoping to get students interested in C-Pep where they can create do similar boat design where the boat is on a magnetic track.

Appendix

(image available in print form)

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(image available in print form)

Resources for Teachers

Atkin, William. *Complete Designs for Forty-Four Modern Boats* . Motorboating: New York, NY. 1941. This book provides a series of boat plans.

Anderson, David and Eberhardt, Scott. *A Physical Description of Flight* . Retrieved July 11, 2004 from the world wide web: http://www.aa.washington.edu/faculty/eberhardt/lift.htm. This website has a wealth of information on Bernoulli’s principle.

Brewer, Ted. *Understanding Boat Design* . International Marine: Camden, ME. 1994. This boat gives great step by step instructions on building your own boat.

Design and Discovery - Curriculum . Retrieved June 28, 2004 from the world wide web: http://www.intel.com/education/design/session02/index.htm. This site gives wonderful curriculum information about getting students to go through the invention process.

Fenn, John B. *Energy, Engines and Entropy. A Thermodynamics Primer* . W.H. Freeman and Company: New York, NY. 1982. This book has useful information on energy and the steam engine.

Gillen, Dave. *Why Is My Paddle Bent?* Retrieved June 28, 2004 from the world wide web: http://www.myccr.com/SectionGear/GearInfo/BentShaft.htm. This website gives great information on canoeing.

Harrison, Slater. *Putt Putt Boats* . Retrieved June 28, 2004 from the world wide web: http://www.sciencetoymaker.org/boat/index.htm. This website gives great instructions on how to build a putt putt boat.

Marshall, Roger. *All About Powerboats* . International Marine. Camden, ME. 2002. This book gives great information about boats.

Michalak, Jim. *Boatbuilding for Beginners (and Beyond)* . Breakaway Books: Halcottsville, NY. 2002. Another good source for building boats.

Sproule, Anna. *James Watt: Master of the Steam Engine* . Blackbirch Press, Inc: CT. 2001. This book gives interesting information about the invention of the steam engine.

Storer, J.D. *A Simple History of the Steam Engine* . John Baker Publishers Ltd: London, England. 1969. This book gives more information about the steam engine.

Winters, John. *The Shape of the Canoe* . Retrieved June 29, 2004 from the world wide web: http://boatbuilding.com/content/Frictional%20Resistance. This website gives wonderful detailed information about how boats interact with water.

Resources for Students

Harrison, Slater. *Putt Putt Boats* . Retrieved June 28, 2004 from the world wide web: http://www.sciencetoymaker.org/boat/index.htm. This website gives great instructions on how to build a putt putt boat.

http://www.sailnet.com/collections/learningtosail/basics/orientation.htm Great drawings of a sailboat with explanation of different parts.

http://travel.howstuffworks.com/steam1.htm A website with great illustrations of steam engines and how they work.

http://www.brainpop.com A great site with small movies about different principles of science and technology. Be aware that you can only run two movies per day if you do not have a subscription.

http://boatdesign.net/gallery/ A site with great galleries at the bottom which show boat plans as well as three-dimensional designs of each boat.

http://www.keveney.com/Engines.html A website with great moving illustrations of different types of engines.