I·D·E·A·S
Integrated Design + Education + Arts Studio

Robotics, Engineering, and the Environment

Instructional Plan

OVERVIEW OF LESSON:

Students will develop an understanding of responsive architecture by researching the benefits of such technology and weighing those benefits against the costs. They will gather data on energy consumption in the United States, identify technologies that could be implemented to reduce that consumption, and design a home with responsive architecture. Finally, students will draw correlations between inventions of the industrial revolution and modern day inventions.

SUBJECT MATTER:

Science
Language Arts
Math
Technology

GRADE LEVEL(S):

6th

CENTER FOR THE ARTS
AT VirginiaTech
Institute for Creativity, Arts, and Technology

Robotics, Engineering, and the Environment

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TIME ALLOTMENT:

Time estimated to complete this lesson is five class periods, but may require some out-of-class work for students.

LEARNING OBJECTIVES:

- Students will be able to:
  1. Give an accurate definition of a sensor and provide examples of how sensors are used in everyday life;
  2. Draw connections between sensors and energy consumption by observing how a sensor can be used to reduce non-renewable energy consumption;
  3. Identify the benefits and costs of architectural robotics from the perspective of multiple stakeholders

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LEARNING STANDARDS:

Content
Standards listed below are not given in their entirety. Rather, the parts of the standards covered by this instruction are included. For complete text of the Virginia Standards of Learning, go to: http://www.doe.virginia.gov/testing/sol/standards_docs/index.shtml

Science:

- 6.1: The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which
  - models and simulations are designed and used to illustrate and explain phenomena and systems; and
  - current applications are used to reinforce science concepts.

- 6.2: The student will investigate and understand basic sources of energy, their origins, transformations, and uses. Key concepts include
  - the role of the sun in the formation of most energy sources on Earth;
  - nonrenewable energy sources;
  - renewable energy sources; and
  - energy transformations.

- 6.6: The student will investigate and understand the properties of air and the structure and dynamics of Earth's atmosphere. Key concepts include
  - natural and human-caused changes to the atmosphere and the importance of protecting and maintaining air quality;

- 6.9: The student will investigate and understand public policy decisions relating to the environment. Key concepts include
    - management of renewable resources;
    - management of nonrenewable resources;
    - cost/benefit tradeoffs in conservation policies.

Language Arts

- 6.1: The student will participate in and contribute to small-group activities.
    - Communicate as leader and contributor.
    - Evaluate own contributions to discussions.
    - Summarize and evaluate group activities.
    - Analyze the effectiveness of participant interactions.

- 6.2: The student will present, listen critically, and express opinions in oral presentations.
    - Distinguish between fact and opinion.
    - Compare and contrast viewpoints.
    - Present a convincing argument.
    - Paraphrase and summarize what is heard.
    - Use language and vocabulary appropriate to audience, topic, and purpose.

- 6.6: The student will read and demonstrate comprehension of a variety of nonfiction texts.
    - Use text structures such as type, headings, and graphics to predict and categorize information in both print and digital texts.
    - Use prior knowledge and build additional background knowledge as context for new learning.
    - Identify questions to be answered.
    - Draw conclusions and make inferences based on explicit and implied information.
    - Differentiate between fact and opinion.
    - Compare and contrast information about one topic, which may be contained in different selections.
    - Identify cause and effect relationships.

- 6.7: The student will write narration, description, exposition, and persuasion.
    - Identify audience and purpose.
    - Use a variety of prewriting strategies including graphic organizers to generate and organize ideas.
    - Organize writing structure to fit mode or topic.
    - Establish a central idea and organization.
    - Select vocabulary and information to enhance the central idea, tone, and voice.
    - Revise sentences for clarity of content including specific vocabulary and information.

- Use computer technology to plan, draft, revise, edit, and publish writing.

- 6.9: The student will find, evaluate, and select appropriate resources for a research product.
  - Collect information from multiple sources including online, print, and media.
  - Evaluate the validity and authenticity of texts.
  - Use technology as a tool to research, organize, evaluate, and communicate information.

Math

- 6.2: The student will
  - investigate and describe fractions, decimals, and percents as ratios;
  - identify a given fraction, decimal, or percent from a representation;
  - demonstrate equivalent relationships among fractions, decimals, and percents; and
  - compare and order fractions, decimals, and percents.
- 6.14 The student, given a problem situation, will
  - construct circle graphs;
  - draw conclusions and make predictions, using circle graphs; and
  - compare and contrast graphs that present information from the same data set.

Technology

See complete Technology standards at http://www.iste.org/standards/nets-for-students/nets-student-standards-2007.aspx

1. Creativity and Innovation
   a. Apply existing knowledge to generate new ideas, products or processes.
   b. Create original works as a means of personal or group expression.
   c. Use models and simulations to explore complex systems and issues.
2. Communication and Collaboration
   a. interact, collaborate, and publish with peers, experts, or others employing a variety of digital environments and media.
   b. communicate information and ideas effectively to multiple audiences using a variety of media and formats.
   d. contribute to project teams to produce original works or solve problems
3. Research and Information Fluency
   b. locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media.
4. Critical Thinking, Problem Solving, and Decision Making
   a. identify and define authentic problems and significant questions for investigation.
   b. plan and manage activities to develop a solution or complete a project
   c. collect and analyze data to identify solutions and/or make informed decisions.

5. Digital Citizenship
   a. advocate and practice safe, legal and responsible use of information and technology.
   b. exhibit a positive attitude toward using technology that supports collaboration, learning, and productivity.
6. Technology Operations and Concepts
   a. understand and use technology systems
   b. select and use applications effectively and productively

Arts
See complete Arts standards at http://artsedge.kennedy-center.org/educators/standards.aspx

Visual Art (5-8)

- Content Standard #1: Understanding and applying media, techniques, and processes
  - Students select media, techniques, and processes; analyze what makes them effective or not effective in communicating ideas; and reflect upon the effectiveness of their choices
  - Students intentionally take advantage of the qualities and characteristics of art media, techniques, and processes to enhance communication of their experiences and ideas
- Content Standard #2: Using knowledge of structures and functions
  - Students employ organizational structures and analyze what makes them effective or not effective in the communication of ideas

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CRITICAL AND CREATIVE THINKING OBJECTIVES:

A complete listing and explanation of critical and creative thinking objectives can be found at www.ideas.soe.vt.edu.

Conceptualizing	Students will verbalize or represent ideas using 2D and 3D representations, movement, or other forms relevant to the context.
Exploring	Students will explore a challenge using a variety of raw materials, stimuli, and experiences.
Metaphorical Thinking	Students will identify words or phrases that are symbolic or representative of other ideas to which they are not literally applicable.
Examining ideas in new and varied ways	Students will engage in activities that provide others' perspectives on a challenge.
Observing	Students will observe things related to the challenge closely to identify details, procedures, and methods
Elaborating	Students will develop ideas and information that expands on what is explicitly given.

Inferring	Students will draw conclusions not explicitly stated based on evidence and reasoning.
Questioning	Students will identify missing or unclear information and ask questions to seek clarity.
Separating	Students will discard ideas that are not relevant to the context.
Relating	Students will identify associations between objects or ideas.
Organizing	Students will arrange information such that connections and relationships are made clear.
Composing	Students will use written, oral, and symbolic language to communicate a summary of thoughts, ideas, and solutions.
Recognizing the existence of a challenge	Students will state the challenge and outline related conditions and scope.
Understanding ability	Students will identify personal abilities that are helpful to meeting goals.
Cognitive restructuring	Students will verbalize positive thoughts about their performance and abilities.
Rejecting stereotypes and prejudice	Students will identify preexisting ideas and opinions regarding a challenge and how they might affect decisions and progress toward goals.
Demonstrating autonomy	Students will initiate activity and exercise self-direction and self-discipline.
Persisting	Students will continue to work until goals are met.
Maintaining intrinsic motivation	Students will identify how the task or problem provides personal satisfaction.
Recognizing relevance	Students will identify personal beliefs and values relating to the context.
Risk-taking	Students will describe how the challenges faced in the process of meeting their goal encouraged them to work beyond their comfort level.

PREREQUISITE KNOWLEDGE:

Prior to this lesson, students should be able to describe the difference between renewable and non-renewable energy sources and give examples of each.

Students should be able to analyze digital artifacts for meaning and purpose.

MEDIA/TECHNOLOGY COMPONENTS:

- Computer with Internet access, video capabilities, sound/speakers and Microsoft Office
- Projection capabilities

- Software that allows students to create storyboards (MS Word, MS PowerPoint are possibilities).
- Access to Internet and all required websites.
- PARTeE robotic FLOWer (included in the kit).
- Hexbug® Micro Robotic Creatures (included in the kit).

MATERIALS:

- Worksheets for student design groups (included at the end of this lesson)

PREPARATION FOR TEACHERS:

- Preview all media materials to check for content appropriateness, thoroughness and understanding.
- Bookmark all necessary websites and check to make sure computer security allows access.

INSTRUCTIONAL PLAN:

Suggested method of lesson procedures:

Introduction: What is a sensor?
Learning Objective: Students will give an accurate definition of a sensor and provide examples of how sensors are used in everyday life.

Gain students' attention by distributing the Hexbugs (included in the kit available at www.ideas.soe.vt.edu) to groups of students and giving them time to play with the robots and discover how they work. By the end of the session, each group should be able to answer the following questions:

1. What supplies the energy that allows them to move? *(batteries)*
2. What determines their motion? *(the antennae sense objects in front of them and cause them to change direction; they have a sound sensor that causes the bugs to react to noise and change direction)*
3. How can you change their motion by manipulating the environment around them? *(clap, make a loud noise, put a barrier in front of them)*

Gather the class back together as a whole group and discuss students' answers to the questions above. Guide the discussion to help students understand that an internal sensor is what helps

the robots determine which way to move. Build a definition of sensors and ask students to think of examples of how they are used in everyday life.

Part Two: Exploring Sensors and Energy Conservation

Learning Objectives:

1. *Students will distinguish between renewable and non-renewable energy sources and compare usage of each of these types of resources in 1970 and 2009.*

2. *Students will draw connections between sensors and energy consumption by observing how a sensor can be used to reduce non-renewable energy consumption.*

Demonstrate the PARTeE robotic FLOWer to the class and allow individual students the opportunity to test its functionality. Next, lead a large group discussion about how it works and what type(s) of sensors might enable it to operate. Explain that the goal in creating this robot was to demonstrate the potential of robotics in architecture. The functions of this machine could be translated into blinds that would open and close automatically according to heat and/or light levels. Increased sunlight levels would cause the blinds to open in the cooler months to provide more natural heat in the home, and rising temperatures would cause the blinds to close during the warmer months to help keep the home cool. ***NOTE: This equipment is fragile. Do not allow students to interact with it unsupervised.***

Continue the class discussion by asking students to suggest why such technology would be beneficial in terms of energy usage. Conduct a brief review of renewable and non-renewable energy sources. Create a column for each type of resource on the board and ask students to add examples to each column. Use the graphic below for a quick review or as a guideline for the group discussion.

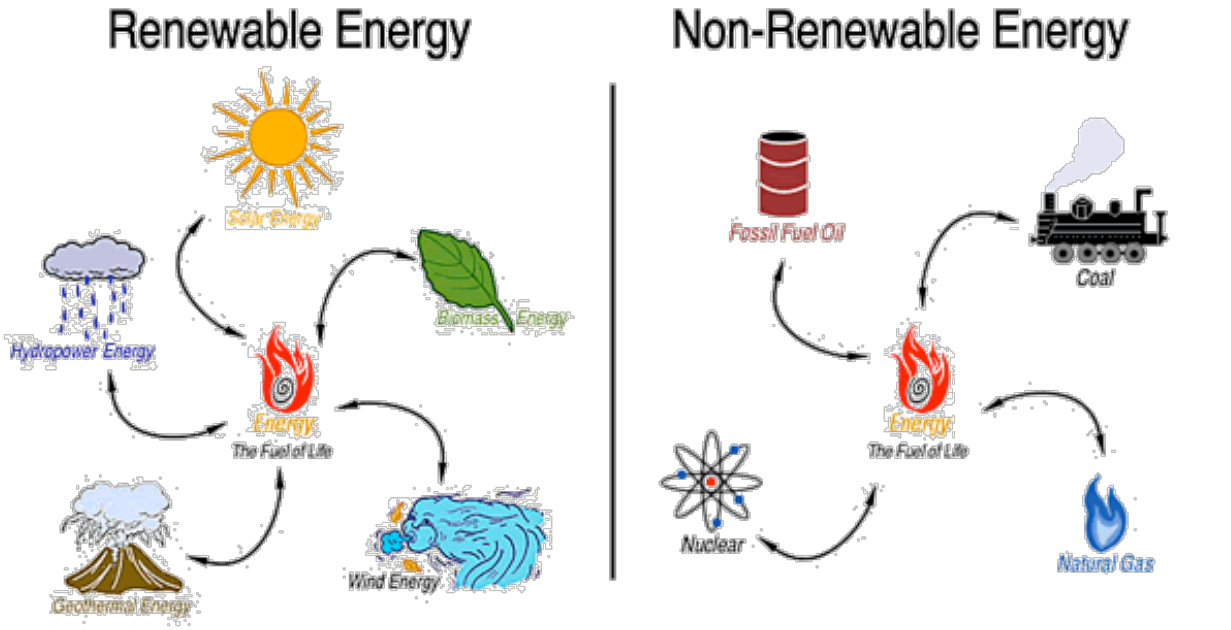

Image courtesy of www.schoolworkhelper.net

With students' knowledge of renewable and non-renewable energy sources activated, discuss examples of things in our homes that use energy every day. Students should be able to list such things as heating and air conditioning units, lights, computers and other electronics, appliances, etc. What types of energy do these things use? *(Answers will vary among classes, but typically will encompass non-renewable energy sources).* Present the pie chart below which illustrates the things that we use daily that require energy. Ask students to guess how much of the energy usage represented in the pie chart is from non-renewable energy sources. The answer is, on average, 92% (see pie graph on next page for more details).

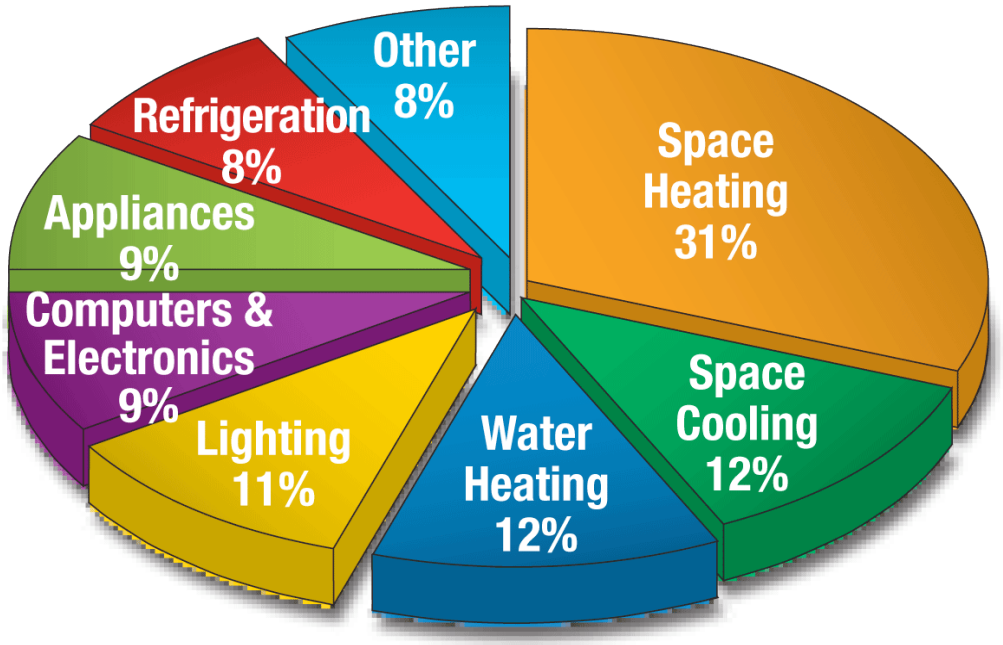

Image courtesy of www.energyauditinstitute.com

Lead students to draw conclusions about the impact of using non-renewable energy. If we continue to use it at such high rates, what will happen to our resources? (*They will ultimately become unavailable)* How can we reduce that possibility? (*Reduce consumption by using less energy or by using alternative energy sources.)* Explain that *responsive architecture* is a new form of architecture that incorporates sensors to reduce energy consumption. The PARTeE robotic FLOWer is a responsive architecture prototype. Move the discussion to talk about energy usage of the PARTeE robotic FLOWer. How does the FLOWer use energy? *(It uses electricity).* What types of renewable energy could its sensors allow it to utilize? *(Solar energy)* What types of energy would such technology conserve? *(Non-renewable energy).*

Divide students into small groups and have them complete the Energy Pie activity included at the end of this lesson. Students will compile data on energy usage in the U.S. in 2009, compare it to energy usage in the U.S. in 1970, and generate a pie chart to graphically represent the uses of energy sources in 2009. Finally, students will compare the usage of renewable and non-

renewable energy sources in 1970 and 2009 to deduce that usage of renewable energy sources

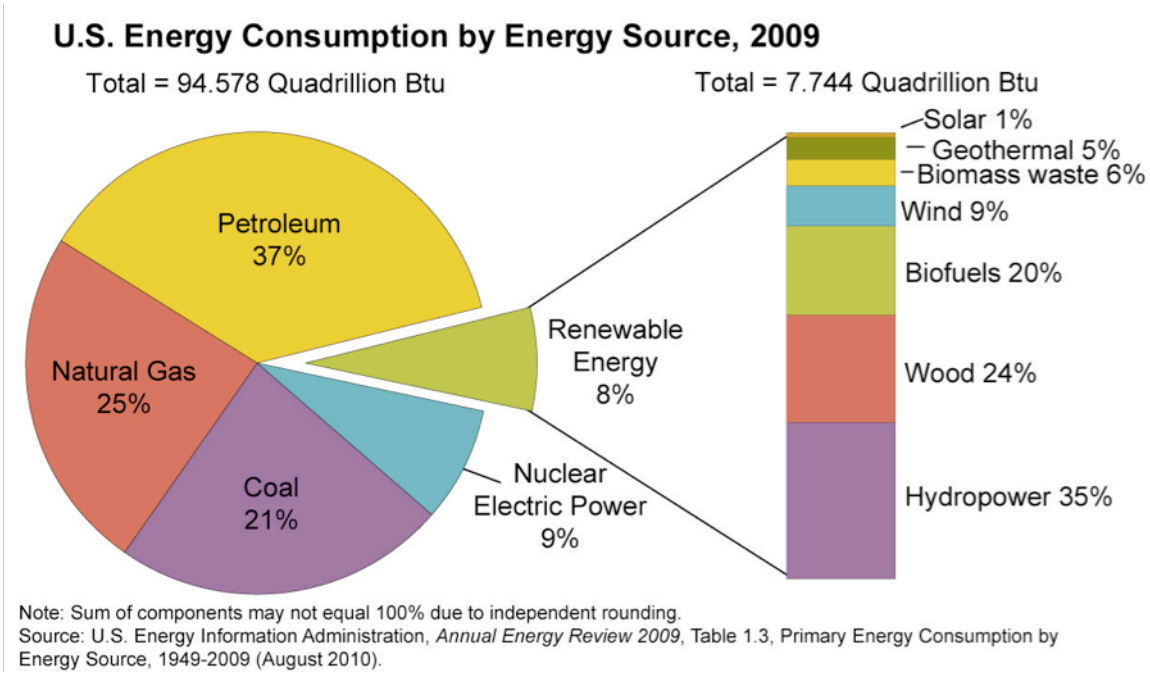

Image courtesy of www.eia.doe.gov

is increasing, but not fast enough to keep pace with our increase in energy usage overall. Discuss the results of the activity as a large group once everyone has compiled the data. Use the chart below to compare students' answers to the actual U.S. Department of Energy data.

Part Three: Exploring Responsive Architecture Design

Learning Objective: Students will work in collaborative groups to design an architecturally responsive home that makes use of sensors and other features to save energy.

Share the Lumenhaus video with students (available at www.lumenhaus.com/documentary) to give students an overview of responsive architecture. Explore each section of the web site (Smart Living, Responsive Living, Green Living, Comfortable Living, and Pavilion Living) to help students develop an appreciation for the different concerns that must be considered when designing with architecturally responsive technology.

Explain to students that they will work together in groups to first identify significant concerns regarding responsive architecture and then design their own version of a home with such technology. The building will utilize sensors to reduce energy consumption and use alternative, renewable energy sources. Students will develop a 3-dimensional or graphic model to present to the class and discuss how their finished product works.

Divide students into teams and distribute the design decisions, perspectives thinking points, and perspectives recording worksheets (attached to the end of this lesson) to each team. Display the list of web sites below as potential resources for teams to utilize as they conduct research.

What is responsive architecture?
http://en.wikipedia.org/wiki/Responsive_architecture
http://www.ehow.com/about_5563042_information-smart-homes.html

Responsive architecture applied in the LumenHaus at Virginia Tech:
http://www.youtube.com/watch?v=1OSrTKklGOI&feature=player_embedded#at=14

Ideas for Energy Conservation:
http://challenge.ecomagination.com/ct/ct_list.bix?c=home

Disadvantages of Smart Homes:
http://www.ehow.com/list_7631272_disadvantages-smart-home.html

Green Homes:
http://planetgreen.discovery.com/videos/worlds-green-homes/
http://www1.eere.energy.gov/kids/roofus/
www.grid-tie.com

Alternative Energy videos:
Check out *Solar Power, Alternative Energy, Energy Conservation, and "This Bulb"*
http://video.nationalgeographic.com/video/player/environment/energy-environment/alternative-energy.html

After students have had ample time to investigate the questions relevant to their assigned perspective, gather the students together as a group and let each team present a few important concepts to consider. Generate a comprehensive list of important considerations when designing an architecturally responsive home.

Have each team generate a prototype for an architecturally responsive building that incorporates all concerns. The prototype can be a 3-dimensional model or a storyboard created electronically. It should include notation of how each feature works and how it saves energy. Once each group has generated a prototype, gather the students together as a whole group and have each team present their concepts.

ASSESSMENTS:

Students will be assessed on the following:

- Pie Chart Activity
- Design Worksheet
- Group Project
- Performance in group activities

*See rubrics attached to this document.

COMMUNITY EVENTS AND CONNECTIONS:

- Contact members of the team that developed Lumenhaus to visit the classroom for a more in-depth discussion of responsive architecture and the Lumenhaus project
- Visit the Lumenhaus in person
- Devise methods to reduce energy consumption in your school and/or homes and develop a community action plan to advertise and implement these methods
- Invite a representative from a local environmental energy agency to come to the class and discuss energy alternatives
- Take the design process a step further and have the entire class incorporate the best concepts of all three designs into a single home. Enter this home design concept into a competition such as the GE Ecomagination Challenge.

CREDITS:

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Additional thanks goes to Sue Magliaro, Director, School of Education and Truman Capone, Director, School of Visual Arts.

This project is funded through the Educational Enhancement Collaboration

Grant program. Support for these grants is provided by:

- Virginia Tech
- Center for the Arts at Virginia Tech
- The Institute for Creativity, Arts, and Technology
- School of Education
- School of Visual Arts
- Collaborative for Creative Technologies in the Arts and Design

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ABOUT THE INTEGRATED DESIGN + EDUCATION + ARTS STUDIO:

The Integrated Design + Education + Arts Studio (IDEAS) is part of the Institute for Creativity, Arts, and Technology (ICAT) at Virginia Tech.

By merging the forces of art and technology into applicable prekindergarten through secondary school (PK-12) programs that strengthen student achievement, Virginia Tech is on the leading edge of a new paradigm in education. ICAT will reach beyond current educational models to fuse arts and technology with content. Our purpose is to strengthen critical and creative thinking skills that prepare students for future careers. ICAT will both generate research and produce learning modules and environments that address real needs identified by educators.

For more information, please see our website at www.ideas.soe.vt.edu.

WE VALUE YOUR FEEDBACK:

Please tell us about how you used the curriculum materials and/or arts project in your classroom. We welcome feedback, suggestions for improvement, and success stories. Find out more at www.ideas.soe.vt.edu.

Get the kit. The IDEAS team has available for loan a number of instructional kits for our various projects. Among other things, each kit includes a FlipCam, a small camera you can use to give us feedback. Because we can't be in the classroom with you, we turn to technology to help provide us a glimpse of the experience you and your students have with the program. That's where the FlipCam comes in.

All we ask is that you document your students engaged with the program and related activities. Feel free to make the filming an integrated part of your experience. Give the camera to the students, do the filming yourself, pass it around to multiple students - however you want to document. Once you are finished with the kit, simply return the camera with the other materials. The Institutional Review Board (IRB) of Virginia Tech requires parent, student, and school assent/consent for participation in this data collection. We provide you with all the necessary permission forms and information for your supervisors.

U.S. ENERGY USAGE COMPARISON

(Adapted from the Energy Pie lesson available at www.eia.gov/kids)

Concepts: Using math to explore changes in the use of energy sources.

Procedure:

1. Find the total amount of Primary Energy Consumption for 1970 and the most recent year in the last column of the attached table. How much more energy do we use now compared to 1970?

2. For the most recent year, use the data in the table to fill in the "Recent Year" columns on page 2. Calculate the percent of total energy from coal, natural gas, petroleum, nuclear, and total renewable sources.

3. Using the data gathered in question 2, fill in the empty pie chart on the page 3. Label the year, total energy consumption, and percent for each energy source.

4. Look up the uses of each energy source on the table at: http://www.eia.gov/kids/energy.cfm?page=about_sources_of_energy-basics. Then, list the uses for each energy source next to the slices of pie.

5. List the energy sources in order from most to least used for both pie charts.

6. Discuss how and why the two energy pies are different. Try to predict what the energy pie will look like in five, ten, or twenty years from now?

Primary Energy Consumption				
Source	1970		Recent year	
	Data Quadrillion British Thermal Units	%	Data Quadrillion British Thermal Units	%
Coal	12.265	18% 12.265/67.844		
Natural Gas	21.795	32% 21.795/67.844		
Petroleum(Oil)	29.795	44% 29.795/67.844		
Nuclear Electric Power	0.239	0.4% 0.239/67.844		
Renewable Energy (total)	4.076	6% 4.076/67.844		
Total	67.844	100%		

Primary Energy Consumption

1970

67.84 Quadrillion British thermal units

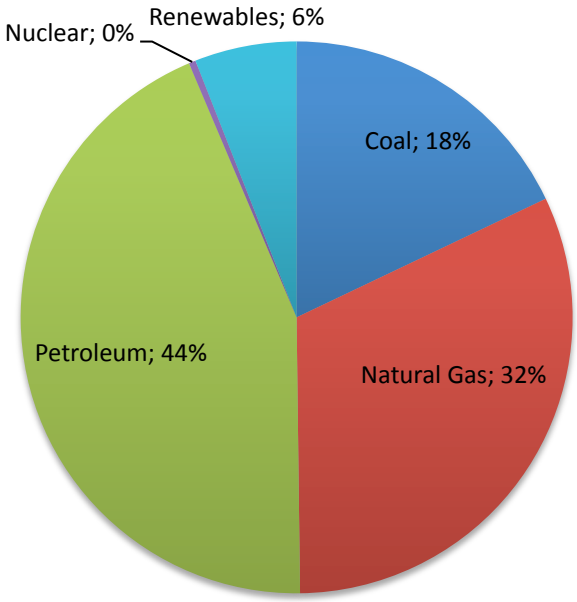

Table 1.3 Primary Energy Consumption by Source, Selected Years, 1949-2009

(Quadrillion Btu)

Year	Fossil Fuels					Nuclear Electric Power	Renewable Energy [1]						Electricity Net Imports [2]	Total
	Coal	Coal Coke Net Imports [2]	Natural Gas [3]	Petroleum [4]	Total		Hydroelectric Power [5]	Geothermal	Solar/PV	Wind	Biomass	Total		
1949	11.981	-0.007	5.145	11.883	29.002	0.000	1.425	NA	NA	NA	1.549	2.974	0.005	31.982
1950	12.347	.001	5.968	13.315	31.632	.000	1.415	NA	NA	NA	1.562	2.978	.006	34.616
1955	11.167	-.010	8.998	17.255	37.410	.000	1.360	NA	NA	NA	1.424	2.784	.014	40.208
1960	9.838	-.006	12.385	19.919	42.137	.006	1.608	.001	NA	NA	1.320	2.929	.015	45.087
1965	11.581	-.018	15.769	23.246	50.577	.043	2.059	.004	NA	NA	1.335	3.398	(s)	54.017
1970	12.265	-.058	21.795	29.521	63.522	.239	2.634	.011	NA	NA	1.431	4.076	.007	67.844
1971	11.598	-.033	22.469	30.561	64.596	.413	2.824	.012	NA	NA	1.432	4.268	.012	69.289
1972	12.077	-.026	22.698	32.947	67.696	.584	2.864	.031	NA	NA	1.503	4.398	.026	72.704
1973	12.971	-.007	22.512	34.840	70.316	.910	2.861	.043	NA	NA	1.529	4.433	.049	75.708
1974	12.663	.056	21.732	33.455	67.906	1.272	3.177	.053	NA	NA	1.540	4.769	.043	73.991
1975	12.663	.014	19.948	32.731	65.355	1.900	3.155	.070	NA	NA	1.499	4.723	.021	71.999
1976	13.584	(s)	20.345	35.175	69.104	2.111	2.976	.078	NA	NA	1.713	4.768	.029	76.012
1977	13.922	.015	19.931	37.122	70.989	2.702	2.333	.077	NA	NA	1.838	4.249	.059	78.000
1978	13.766	.125	20.000	37.965	71.856	3.024	2.937	.064	NA	NA	2.038	5.039	.067	79.986
1979	15.040	.063	20.666	37.123	72.892	2.776	2.931	.084	NA	NA	2.152	5.166	.069	80.903
1980	15.423	-.035	20.235	34.202	69.826	2.739	2.900	.110	NA	NA	2.476	5.485	.071	78.122
1981	15.908	-.016	19.747	31.931	67.570	3.008	2.756	.123	NA	NA	R2.596	R5.477	.113	76.168
1982	15.322	-.022	18.356	30.232	63.888	3.131	3.266	.105	NA	NA	R2.663	6.034	.100	73.153
1983	15.894	-.016	17.221	30.054	63.154	3.203	3.527	.129	NA	(s)	R2.904	R6.561	.121	R73.038
1984	17.071	-.011	18.394	31.051	66.504	3.553	3.386	.165	(s)	(s)	R2.971	R6.522	.135	R76.714
1985	17.478	-.013	17.703	30.922	66.091	4.076	2.970	.198	(s)	(s)	R3.016	R6.185	.140	R76.491
1986	17.260	-.017	16.591	32.196	66.031	4.380	3.071	.219	(s)	(s)	R2.932	R6.223	.122	R76.756
1987	18.008	.009	17.640	32.865	68.522	4.754	2.635	.229	(s)	(s)	R2.875	R5.739	.158	R79.173
1988	18.846	.040	18.448	34.222	71.556	5.587	2.334	.217	(s)	(s)	R3.016	R5.568	.108	R82.819
1989	19.070	.030	19.602	34.211	72.913	5.602	2.837	.317	.055	.022	R3.159	R6.391	.037	R84.944
1990	19.173	.005	19.603	33.553	72.333	6.104	3.046	.336	.060	.029	R2.735	R6.206	.008	R84.651
1991	18.992	.010	20.033	32.845	71.880	6.422	3.016	.346	.063	.031	R2.782	R6.238	.067	R84.606
1992	19.122	.035	20.714	33.527	73.397	6.479	2.617	.349	.064	.030	R2.932	R5.992	.087	R85.955
1993	19.835	.027	21.229	33.744	R74.835	6.410	2.892	.364	.066	.031	R2.908	R6.261	.095	R87.601
1994	19.909	.058	21.728	R34.561	R76.257	6.694	2.683	.338	.069	.036	R3.028	R6.153	.153	R89.257
1995	20.089	.061	22.671	R34.436	R77.257	7.075	3.205	.294	.070	.033	R3.101	R6.703	.134	R91.169
1996	21.002	.023	23.085	35.673	R79.782	7.087	3.590	.316	.071	.033	R3.157	R7.166	.137	R94.172
1997	21.445	.046	23.223	R36.159	80.874	6.597	3.640	.325	.070	.034	R3.105	R7.175	.116	R94.761
1998	21.656	.067	22.830	R36.816	R81.369	7.068	3.297	.328	.070	.031	R2.928	R6.654	.088	R95.178
1999	21.623	.058	22.909	R37.837	R82.427	7.610	3.268	.331	.069	.046	R2.963	R6.677	.099	R96.812
2000	22.580	.065	23.824	R38.263	R84.732	7.862	2.811	.317	.066	.057	R3.008	R6.260	.115	R98.970
2001	21.914	.029	22.773	R38.185	R82.902	R8.029	2.242	.311	.065	.070	R2.622	R5.311	.075	R96.316
2002	21.904	.061	23.558	R38.225	R83.749	R8.145	2.689	.328	.064	.105	R2.701	R5.888	.072	R97.853
2003	22.321	.051	R22.831	R38.808	R84.010	7.959	2.825	.331	.064	.115	R2.807	R6.141	.022	R98.131
2004	22.466	.138	R22.909	R40.292	R85.805	8.222	2.690	.341	.065	.142	R3.010	R6.247	.039	R100.313
2005	22.797	.044	R22.561	R40.391	R85.793	R8.161	2.703	.343	.066	.178	R3.117	R6.406	.084	R100.445
2006	22.447	.061	22.224	R39.955	R84.687	R8.215	2.869	.343	.072	.264	R3.277	R6.824	.063	R99.790
2007	22.749	.025	R23.702	R39.769	R86.246	R8.455	2.446	.349	.081	.341	R3.503	R6.719	.107	R101.527
2008	R22.385	.041	R23.791	R37.279	R83.496	R8.427	R2.511	R.360	R.097	R.546	R3.852	R7.366	.112	R99.402
2009P	19.761	-.024	23.362	35.268	78.368	8.349	2.682	.373	.109	.697	3.883	7.744	.117	94.578

[1] Most data are estimates. See Tables 10.1-10.2c for notes on series components and estimation.
[2] Net imports equal imports minus exports. A minus sign indicates exports are greater than imports.
[3] Natural gas only; excludes supplemental gaseous fuels. See Note 1, "Supplemental Gaseous Fuels," at end of Section 6.
[4] Petroleum products supplied, including natural gas plant liquids and crude oil burned as fuel. Does not include biofuels that have been blended with petroleum—biofuels are included in "Biomass."
[5] Conventional hydroelectric power.

R=Revised. P=Preliminary. NA=Not available. (s)=Less than 0.0005 and greater than -0.0005 quadrillion Btu.

Notes: • See "Primary Energy Consumption" in Glossary. • See Table E1 for estimated energy consumption for 1635-1945. • See Note 3, "Electricity Imports and Exports," at end of Section 8. • Totals may not equal sum of components due to independent rounding.

Web Page: For all data beginning in 1949, see http://www.eia.gov/emeu/aer/overview.html.

Sources: Tables 5.12, 6.1, 7.1, 7.7, 8.1, 8.2a, 10.1, 10.3, A4, A5, and A6.

DESIGN DECISIONS HANDOUT:

Your group's task is to design an architecturally responsive home that makes use of sensors and other features to save energy.

1. Each person in your group chooses a perspective – a way to look at the decisions being made.
    a. A person who will live in the house (comfort, function, and aesthetics)
    b. A person who will pay for the house (building costs and maintenance)
    c. A great-great grandchild of either or both of the above (environmental responsibility)

2. With your perspective in mind, take a look at the following websites. Think about how the home could be designed. Use the *Perspectives Thinking Points* handout to guide your research, and record your findings on the appropriate *Perspectives Recording Sheet* handout.
    What is responsive architecture?
    - http://en.wikipedia.org/wiki/Responsive_architecture
    - http://www.ehow.com/about_5563042_information-smart-homes.html

    Responsive architecture applied in the LumenHaus at Virginia Tech:
    - http://www.youtube.com/watch?v=1OSrTKklGOI&feature=player_embedded#at=14

    Energy Usage Basics:
    - http://www.eia.doe.gov/kids/energy.cfm?page=3

    Ideas for Energy Conservation:
    - http://challenge.ecomagination.com/ct/ct_list.bix?c=home
    - http://www1.eere.energy.gov/kids/renergy.html

    Disadvantages of Smart Homes:
    - http://www.ehow.com/list_7631272_disadvantages-smart-home.html

    Green Homes:
    - http://planetgreen.discovery.com/videos/worlds-green-homes/ (click the "Playlist" tab under the video window)
    - http://www1.eere.energy.gov/kids/roofus/
    - www.grid-tie.com

    Alternative Energy videos:
    - Check out Solar Power, Alternative Energy, Energy Conservation, and "This Bulb" http://video.nationalgeographic.com/video/player/environment/energy-environment/alternative-energy.html

3. Work with members of your group to design a house that meets the needs of all the perspectives.
    a. Prepare a model or floor plan of your house.
    b. List the features that use responsive architecture to conserve energy.
    c. Keep a record of the decisions that are made. "We had to decide between [Option A] and [Option B] (or more options). We chose [Option] because of [which perspective]."
    d. Write a paragraph about how your group balanced the needs of all the perspectives.

PERSPECTIVES THINKING POINTS HANDOUT:

Consider these thinking points for each perspective.

A person who will live in the house (*comfort, function, aesthetics*)

- How much electricity will I need on a daily or monthly basis for my family? How much energy can I generate using alternative energy sources?
- How much space do I need for my family members? How can I maximize the energy efficiency of that space? Which rooms in my home will use the most energy? Which rooms should I consider when implementing architectural robotics and other smart technologies?
- How can a home respond to environmental conditions?

A person who will pay for the house (*building cost, maintenance*)

- What types of materials are used in responsive architecture? What is the difference in cost between an architecturally responsive home and a traditional home?
- Which smart technologies will save me the most money? Considering the up-front cost of the technology and the monthly savings as a result, how long will it take for me to begin actually saving money?

A great-great grandchild (*environmental responsibility*)

- In what ways can different rooms of a home be designed to be "green"?
- What resources are most valuable that you hope to have access to, and what things can your great-great grandparents do to help preserve them?
- If your great-great grandparents do nothing to reduce their energy consumption and utilize alternative energy sources, what will you be missing when you are their age? (Think about things other than energy resources)
- What advice would you give to your great-great grandparents to help make the world as comfortable for you as it was for them?

PERSPECTIVES RECORDING SHEET: Homeowners
(Building Costs, Maintenance)

As you consider the points listed on the perspectives thinking points handout, record your findings below. Include the source where you found the information so you can return to that information for future reference.

What types of materials are used in responsive architecture? Which materials will be most beneficial to your home design in terms of cost?

What is the difference in cost between an architecturally responsive home and a traditional home?

Which smart technologies will save me the most money?

Considering the up-front cost of the technology and the monthly savings as a result, how long will it take for me to begin actually saving money?

PERSPECTIVES RECORDING SHEET: Home Dwellers
(Comfort, Function, Aesthetics)

As you consider the points listed on the perspectives thinking points handout, record your decisions below.

How much energy will I need on a daily or monthly basis for my family?

How much energy can I generate using alternative energy sources?

How much space do I need for my family members? How can I maximize the energy efficiency of that space?

Which rooms in my home will use the most energy? Which rooms should I consider when implementing architectural robotics and other smart technologies?

PERSPECTIVES RECORDING SHEET: Great-Great Grandchildren
(Environmental Responsibility)

As you consider the points listed on the perspectives thinking points handout, record your decisions below.

In what ways can different rooms of a home be designed to be “green”?

What resources are most valuable that you hope to have access to, and what things can your great-great grandparents do to help preserve them?

If your great-great grandparents do nothing to reduce their energy consumption and utilize alternative energy sources, what will you be missing when you are their age? (Think about things other than energy resources)

What advice would you give to your great-great grandparents to help make the world as comfortable for you as it was for them?

SMART HOME DESIGN RUBRIC:

Smart Home Design	3	2	1	0
Part One: Design Decisions				
Group Findings	Student addresses all questions from the perspectives worksheet thoroughly and uses proper grammar and punctuation	Student addresses all questions from the perspectives worksheet but is not thorough or uses improper grammar and punctuation	Student omits one or more questions from the perspectives worksheet	Student does not complete perspectives worksheet
Group Presentation	Student contributes to the group presentation by clearly stating factors to consider from his/her assigned perspective	Student contributes to group presentation by stating factors to consider, but presentation is unclear or inaccurate	Student contributes to group presentation but does not present information orally	Student does not contribute to group presentation
Part Two: Home Design				
Group Collaboration	Student contributes to group work by contributing ideas and completing equal share of work	Student contributes to group work by contributing ideas *OR* completing equal share of work	Student contributes to group work but does not complete an equal share of the work	Student does not contribute to the group work with ideas or work

3-D Model or Storyboard	3-D model or storyboard is presented in a polished format which incorporates concerns from all parties involved	3-D model or storyboard is either unpolished or omits concerns from one of the involved parties	3-D model or storyboard is unpolished and omits concerns from two of the involved parties	3-D model or storyboard is unpolished and does not address concerns of any of the parties
Narrative Notation	3-D model or storyboard includes notation to demonstrate how the features address all important concerns	3-D model or storyboard includes notation to demonstrate how the features address some important concerns	3-D model or storyboard includes notation to demonstrate how the features address few important concerns	3-D model or storyboard does not include notation to demonstrate how the features address important concerns
Efficiency	3-D model or storyboard thoroughly addresses concerns of all three perspectives	3-D model or storyboard addresses concerns of all perspectives but is not thorough	3-D model or storyboard omits concerns of one or more perspectives	3-D model or storyboard does not address concerns of three perspectives
Column Total				
Rubric Total	_____ out of 18			

CRITICAL AND CREATIVE THINKING RUBRIC:

Critical and Creative Thinking	3	2	1	0
Conceptualizing	Student uses storyboards/3-D models and written language to fully represent ideas for a home design.	Student uses storyboards/3-D models and written language to represent some of the ideas for a home design.	Student uses storyboards/3-D models and written language to represent few ideas for a home design.	Student fails to represent ideas for home design.
Embracing Multiple Points of View	Student uses concerns from homeowners, home dwellers, and grandchildren to inform the home's design.	Student omits concerns from homeowners, home dwellers, or grandchildren when planning the home's design.	Student uses concerns from only one of homeowners, home dwellers, or grandchildren when planning the home's design.	Student does not utilize concerns of stakeholders when planning the home's design.
Remaining open-minded	Student identifies how ideas from others influenced his/her own ideas.	Student identifies how some ideas from others influenced his/her own ideas.	Student does not identify ideas that influenced his/her own ideas.	Student rejects others' ideas.
Identifying worth/ applicability of ideas	Student makes plenty of positive statements about the value of his/her ideas to the context.	Student makes a few positive statements about the value of his/her ideas to the context.	Student makes no positive statements about the value of his/her ideas to the context.	Student makes negative statements about the value of his/her ideas to the context.
Column Total				
Rubric Total		_____ out of 12		