

# An Innovative Method to Teach Physics to 4-H Students

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## Need

Rod Paige, The U.S. Secretary of Education stated, "Technological literacy is a new fundamental for our education system. All of us must develop this literacy to make wise decisions in our roles as citizens and in our personal lives. America needs inventors, engineers, doctors, computer designers, and scientists. We need botanists, veterinarians, chemists, astronomers, and naturalists. But in order to pursue these careers, our children need an excellent grounding in science, and right now our system is not delivering it." (Paige, 2001). This need to impart technological literacy to our youth is even more vital for a state such as Alabama, since it has historically received relatively low levels of Federal research and development funding (EPSCOR).

According to the *Alabama Kids Count 1997 & 1998 Data Books*, the number of students in the state that graduate on time has declined, from 71.6% in 1987 to 63.1% in 1995 and 60.8% in 1997. Further, the number of college graduates reported in the 1997 Alabama County Data Book is less than 16% of the general population. Thirty five counties in the state of Alabama have less than 10% of the general population with college degrees. There is a clear need to find ways to encourage young people in Alabama to prepare better for a meaningful and rewarding career. As our society becomes more and more science and technology oriented, there is a need to motivate our youth to consider technical areas of study and to develop a better understanding of what the 21st century workplace will be like.

Traditional methods of teaching do not seem to reach these students (Wulf, 2002). There is a strong need for creative and fun learning experiences where students will become more excited about and interested in science, math and technology. Organizations that work with young people in Alabama, such as 4-H, have realized the need to develop new and innovative camps to expose the students to science, technology, and engineering in an exciting and positive setting. The Alabama 4-H program is 100 years old and caters primarily to youth from rural and disadvantaged counties. Its focus in the past has been mainly on offering courses related to agriculture and projects such as public speaking, food demonstrations, woodwork-

ing, electric demonstrations, photography, plant and soil science, compact tractor operations, and raising animals. The 4-H program is well-established and well-respected for its contributions to the community by the citizens of Alabama (Mulvaney, 2002) and is now reaching students in urban settings as well. The 4-H program in the state caters to 180,000 students, with about 60,000 based in class-room based clubs, 4,000 in camps, 40,000 in nutrition education, and 80,000 in school enrichment programs. There are approximately eighty 4-H agents who work closely with the clubs in the state. Many students come from rural communities where their educational opportunities are limited. Many of the adult leaders themselves may not have attended college. The exposure of students to science topics and "hands-on" experiments is limited, given the paucity of resources in the rural school districts of Alabama. The expenditure per pupil in rural schools is \$5,400 compared to \$6,050 in city schools. One hundred and fifty of the schools in the state, largely in rural areas, were in "alert" or "caution" status compared to the 1,122 schools that were "clear" during 2000 (State of Alabama, 2000).

Therefore, the 4-H program wanted to develop a one-day camp with the following goals. In this camp, each student will

- (a) learn about, experience, and use information technologies to explain a science project
- (b) be motivated to learn more about science, in particular physics
- (c) experience science learning outside of formal classroom environments

In addition, each parent/ coordinator will

- (a) be stimulated to support their children's science learning endeavors
- (b) become informed proponents for high-quality science education

## Development of Instructional Materials

The 4-H Sci-Tech Day Camp was developed by the Laboratory for Innovative Technology and Engineering Education (LITEE), Auburn University, which designed and executed an informal educational program for 4-H members, parents, and club leaders. LITEE constructed the 4H Sci-Tech day

## Abstract

The need to impart technological literacy to youth is vital for a state such as Alabama, since it has historically received relatively low levels of Federal research and development funding (EPSCOR). Thirty five counties in the state of Alabama have less than 10% of the general population with college degrees. As our society becomes more and more science and technology oriented, there is a need to motivate our youth to consider technical areas of study and to develop a better understanding of what the 21st century workplace will be like. A pilot study was conducted at a camp in Birmingham, AL, where instructional materials were presented using cartoon characters, connection to a real-world company problem, and a hands-on experiment. Twenty-four students from six counties in Alabama participated in the camp. Evaluation results show that the pilot study engaged the students in the learning process, brought together individuals and organizations from the informal and formal education communities, and benefited the 4-H students tremendously. These results lead us to conclude that the U.S. government and private organizations need to invest in development of innovative instructional materials so that young students could perform hands-on experiments, use information technologies to document the results of the experiments, and thereby connect science & math theories to real-world applications.

camp program by incorporating recent advances in disciplinary content, research on teaching and learning, and instructional technologies into the curriculum. This unique experience was developed through use of multimedia, hands-on learning, and a community-based approach that involved a diverse mix of students, parents and 4-H Adult Volunteers. The intent of this community-based approach was to increase interest, understanding, and interaction with physics topics by individuals of all ages. The LITEE program developed specific instructional materials in consultation with Technovations, RLS, LLC, a physics teacher, 4-H community leaders, and LITEE students. These instructional materials are available from Technovations for use in other settings.

## Participants at the Day Camp

On September 7<sup>th</sup> 2002, ACES/4-H hosted a Sci-Tech Day Camp at the Botanical Gardens in Birmingham, Alabama. The attendees and participants consisted of students, parents, 4-H Adult Volunteers, and ACES agents. The twenty-four students represented six Alabama counties (Perry, Limestone, Choctaw, Houston, Montgomery, and Randolph). The students ranged in age from nine to fourteen; ten of the students were boys; 14 were girls. Of the twenty-four students participating, four were African American. Two schoolteachers and three student assistants conducted instructional and hands-on learning segments of the camp. Two faculty members and one ACES/4-H coordinator managed the day camp program and its logistics.

## Instructional Methodology

The one-day program comprised the following elements: a pre-test to measure the audiences' familiarity with physics topics, a session by a teacher explaining basics of energy and physics, a session on using digital cameras and powerpoint slides, a hands-on experiment where the students generated electricity from fruits and documented the process using photos and videos, a computer lab session where the students developed powerpoint slides, a presentation session where the student teams presented the results of their experiments, and a post-test. Students were informed that they were participating in an "Energy Warrior" Boot Camp and two characters "Captain Current" and "Sergeant Circuit" would lead them through an adventure that would develop their existing knowledge of physics related to Energy. At the end of the successful completion of the day camp, each student will receive an "Energy Warrior Boot Camp" certificate. Technovations developed powerpoint slides that explained the basics of energy and combined these slides with a real-world case study developed by

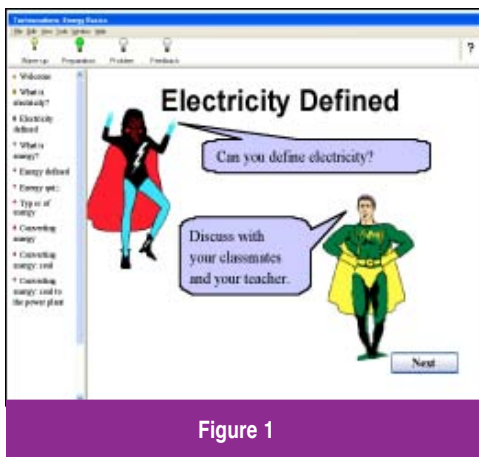


Figure 1

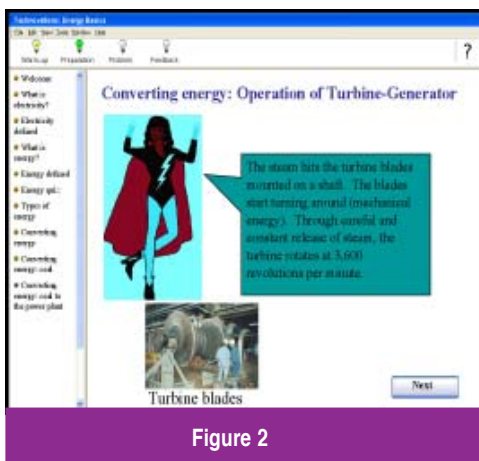


Figure 2

LITEE entitled, "Della Case Study" (Raju and Sankar, 2000). Examples of the slides used in the day camp are shown in Figures 1 and 2. An agenda for the day camp is shown as Appendix 1. The details of the sessions are described next.

### Pre-Test

Before starting the camp, the students and adult leaders completed a pre-test that included questions on energy and physics and a questionnaire that asked them to rank their familiarity with physics topics and information technology knowledge and skills (Appendices II and III).

### Basics of Energy

Following the pre-test the first learning session began. During the first session, an instructor explained the basics of energy and physics. The energy and physics principles taught in this segment were related to the real world examples of energy that the participants use everyday.

For example, students learned how a Coal Fired Power Plant converts the potential energy stored in coal into kinetic energy. They also saw actual Power Plant operations, since videos and digital photographs were integrated into the presentation. In this session they saw how mechanical energy is used to turn the rotor shaft in the turbine generator

to create the electro-magnetic energy which supplies our homes with electricity. The design of the multi-media presentation demonstrated the capabilities of PowerPoint and informally illustrated the use of Information Technology to the students. Exposure to Information Technology was reinforced several times during the day camp program.

### **Hands-on Experiment: Deriving Electricity from Fruits**

In order to reinforce the theories learned in the first session and to add a fun element, during the second session the students performed a hands-on experiment. Here they studied basic principles of electrochemical cells using the juice of several fruits as the electrolytes and discovered that common fruits generate electricity. They were provided with different materials that would serve as electrodes. The electrode materials consisted of a graphite pencil, an iron nail, a magnesium strip, and a zinc-coated nail. With a voltmeter each student team was asked to measure the electricity generated when two of the electrode materials were inserted in the fruit. They tested five different fruits: apple, grapefruit, lemon, banana, and pear. Each team measured and recorded the voltage reading for each electrode and fruit combination (Figure 3 and 4). This hands-on experiment taught the students about measuring voltage, identifying the change in voltage over time, and documenting the test results. They were provided a document where the experimental results were tabulated and questions pertinent to the experiment were answered (Appendix IV).

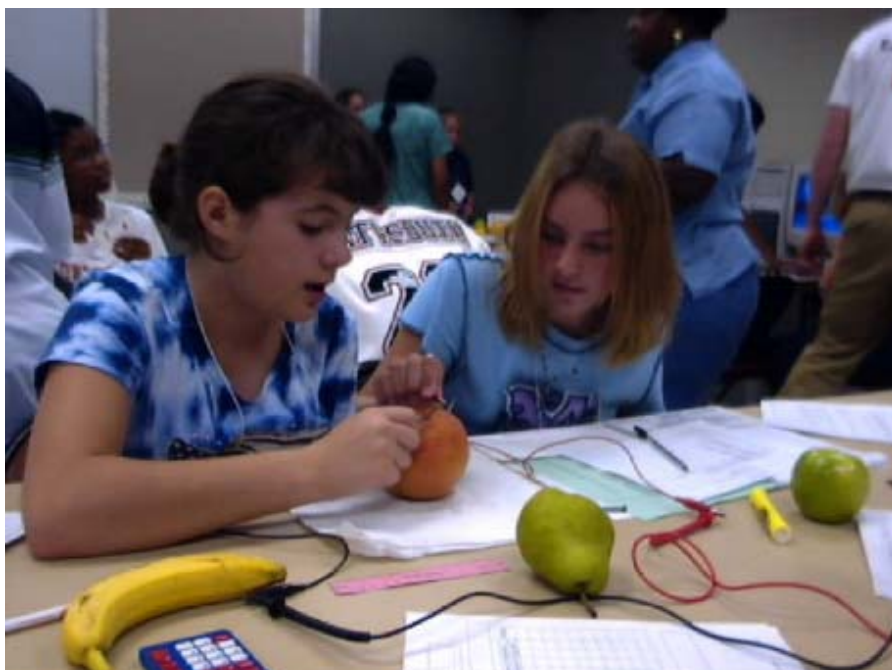


Figure 3

presented their work in front of their peers, parents, and adult volunteers. Each student team shared in the spokesperson responsibilities and communicated a portion of their team's presentation. Every group used the PowerPoint presentation they created in the previous session to showcase the results of their fruit experiment. Examples of their presentations, videos, and photos are available on the website: [www.auburn.edu/research/liitee](http://www.auburn.edu/research/liitee) website.



Figure 4

### **Technology Lesson & Demonstration**

During the third session, the students were provided with an overview of how to develop a PowerPoint presentation. Instructors taught the basics of creating a new PowerPoint presentation and incorporating text, building graphs, inserting pictures, sound/voice files, and videos. After the instructions, the students were given time to work on their presentations (Figure 5).

### **Hands-on Technology Lab: PowerPoint**

In the next session, each student team developed a PowerPoint presentation that communicated their Fruit Experiment findings. As the students built their presentations, instructors, parents, and 4-H adult volunteers were available for student assistance (Figure 6). Using their own creativity in the PowerPoint design process, each team utilized the pictures and videos that they created using the digital camera to help convey what they learned (Figure 7).

### **Team Presentations & Website Creation**

In the final session, the student teams pre-

### **Post-Test**

Prior to the camp's conclusion, the students completed a post-test that covered the topics fea-

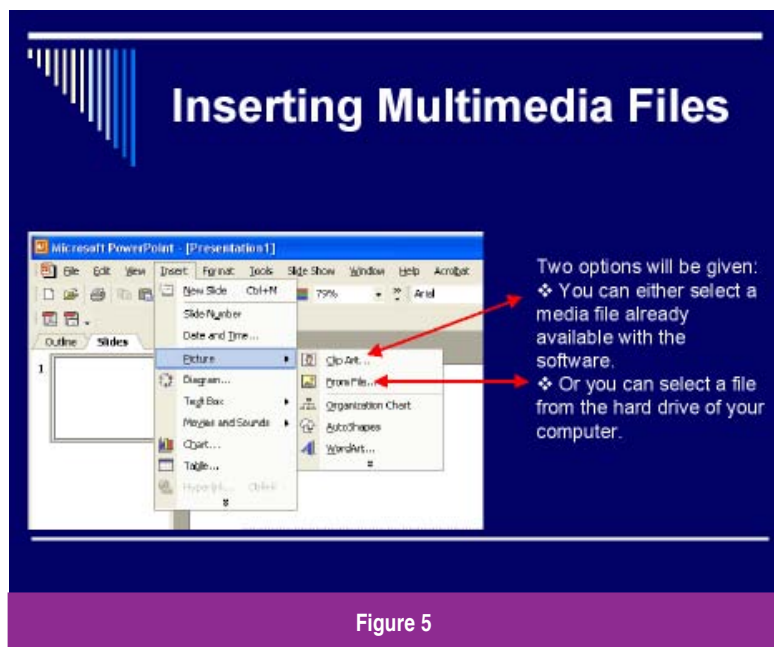


Figure 5

tured in the day camp curriculum. Although the questions were different from the pre-test, they still included questions on energy and physics. However they completed the same questionnaire that they had earlier completed which asked them to rank their familiarity with physics and information technology topics (Appendix III).

### Focus Group Sessions

The adult volunteers and parents were invited to participate in two focus group sessions that were conducted when the students were participating in the lab activities. Half of the adults participated in the first focus group while the other half participated in the lab with the students. These adult groups exchanged roles during the second focus group session. This gave each adult the opportunity to participate with students in a lab exercise and provide feedback in the focus group. The ACES coordinator and a LITEE representative facilitated the focus group activities. The purpose of the focus group was to solicit feedback from the adults about the effectiveness of the day camp. The focus group provided critical information about the value of the camp's curriculum, and how the camp was organized and executed.

### Experimental Results

The pre and post-tests, questionnaires, and comments were analyzed in order to determine the effectiveness of the pilot camp in meeting the goals. Fifteen questions measured the knowledge obtained by students and adults on concepts of energy, physics, and information technology by comparing the results of a pre and a post test that they took. We chose to do a 2 sample t-test in order to test the null hypothesis, which states that there is no difference between the results of the pre-test and post-test. The test result was significant at  $\alpha = .05$ ; thus, we can say with 95% confidence that, on average, the participants answered 0.24 to 3.8 more questions correctly on the post-test than on the pre-test (Figure 8). This result shows that the camp met the educational objective of making both the students and adults more proficient in physics topics.

In addition, the other questionnaires measured the self-perception of the participants on the effectiveness of the camp. Analysis of the questions related to energy showed that the students and adults perceived that they had a better understanding of energy, physics, and IT concepts due to the camp. Analysis of questions related to their understanding of physics concepts showed a significant improvement (Figure 9). It is interesting to note that both children and adults did not perceive that they knew about physics topics to a reasonable level (below score of 3) before the camp. After the



Figure 6

camp, their perceptions improved to the 3-level.

The students tabulated their data and used the data to answer questions about the experiment. For example, one question was to find out how long the voltage readings continued and what would happen if the voltmeter leads were reversed. Of the students participating, ten indicated that they had never performed this type of hands-on experiment prior to coming to this day camp. Approximately 20 of the 24 students participating had never used a PowerPoint to create a presentation prior to this camp.

Analysis of questions related to solving problems and relating science to real-world engineering problems, also showed scores of 3 and above in a 5-point Likert scale. The questions on having fun in the workshop received a very high score of 4.5 and above, showing that both the students and the adults enjoyed the camp. Questions completed by adult leaders on improvement in perceived skill development, self-reported learning, communications skills, and learning from others were all above 4.0 on the 5-point Likert scale. All these results show that the attendees perceived the camp to be very useful in meeting the goals. These results were further reinforced by the comments made by the students such as:

- *It was fun and educational;*
- *The volunteers were very helpful;*
- *I liked PowerPoint presentation;*
- *I loved the hands-on stuff;*
- *I learned a lot and it and the teachers made it easy to understand;*
- *I liked the team activities;*
- *I am a slow learner and I had lots of fun and*



Figure 7

*learned a lot.*

The adult leaders also expressed strong appreciation for the outcome of the camp as shown by the comments such as:

- *Hands on experiments were great;*
- *It was good to see kids working together, learning from each other;*
- *Students got a chance to learn presentation skills and put them into use;*
- *I was impressed by the expertise of trainers;*
- *Students and adults were engaged during every exercise;*
- *I liked how the camp used the material learned in the experiments and applied that to the content used in PowerPoint development;*
- *The quality of the material used in the camp was first rate; You could really see some very positive attitudes arise during the camp;*
- *This program made it easy for me to learn the science and math concepts so that I can help my children learn using this program.*

## Summary and Conclusions

The statistical results and the comments from both the students and adult leaders show that the methodology adopted in this program motivated the students to learn more about science, in particular physics. Students were excited to learn about physics concepts once they were able to conduct hands-on experiments and use information technology (such as photos, slides) to communicate the findings. The program needed the dedicated services of several teachers, university faculty members, and students who worked together to make it a success. This project showed us that young students in Alabama are very much interested in exploring science topics much further, but are reluctant to do so without hands-on experimentation and use of information technology tools. Once the instructional materials have been fully developed and tested, this program could positively impact the STEM capabilities and the future of its more than 100,000 student participants in the state.

Even though the results were very successful, the 4-H program does not have the funding needed to develop any more modules nor monies available to hire the services of a teacher to explain physics concepts. They are normally limited to using the services of volunteer parents or extension agents to conduct the camps. In addition, the students in this program do not have the family support to afford the camp even if it is offered on a cost-only basis. This is no surprise given that 27% of children in Alabama live in families where no parent has full-time year-round employment and 21% of children live in poverty according to 2001 data (Kids Count, 2004). The project team has intentions to apply for grants in order to develop the program further. Until such funding support is available, it is difficult to implement this program at a state-wide level. The U.S. needs to invest in development of innovative instructional materials and needs to train young students on science & math applications, not theories alone. Students and parents are willing to attend the camps and go through the experiences, but massive investments from government and private sector are needed for such camps to become common place.

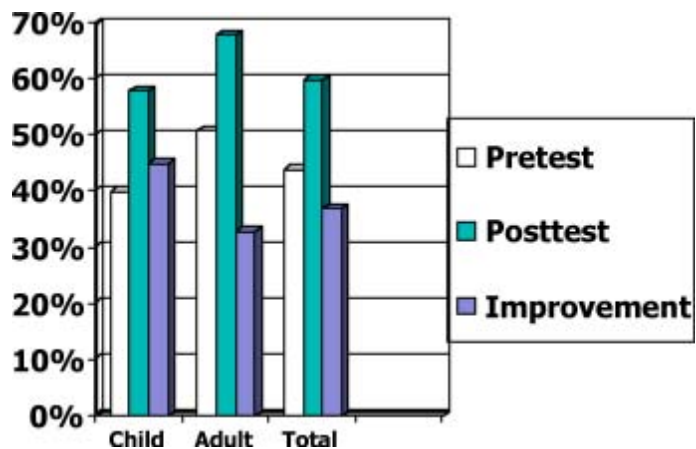


Figure 8

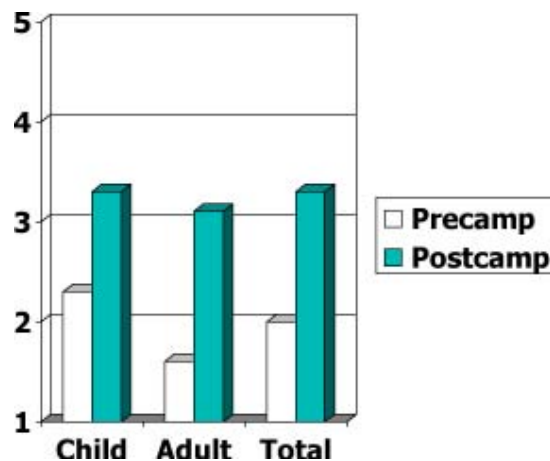


Figure 9

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**P.K. Raju** is Thomas Walter Professor of Technology Management & Director of Auburn Engineering Technical Assistance Program in the Mechanical Engineering Department at Auburn University. Dr. Raju has directed and managed a variety of sponsored research and development projects. These projects have dealt with different aspects of acoustics, vibration, noise control, non-destructive evaluation, and engineering education. These projects have been funded by industries (John Deere, Louisiana Pacific Corporation, Wheelabrator, American Gas Association) and government and international agencies (UNDP, NASA, NSF, DOD, DOE, NIST) and totals over \$4.1 million. Dr. Raju has authored or edited 18 books, published five book chapters and has published a total of 129 papers in journals and conference proceedings. He also is the co-author of eight books on engineering management published by Tavenner Publishers in 2000 and 2001. Dr. Raju is a member of the ASME, ASEE, INCE, ASA, ASNT, INCE. He served on the executive committee (1992-1996), and as Chairman of the ASME Noise Control and Acoustics Division (1996-1997), and served as Assistant Vice President Region XI (1994-1995). He also served as president of the Alpha Upsilon Chapter of Phi Beta Delta, Honor Society for International Scholars (1996-1997). He could be contacted at [pkraju@eng.auburn.edu](mailto:pkraju@eng.auburn.edu).



**Chetan S. Sankar** is the Thomas Walter Professor of Management at Auburn University's College of Business. He received his Ph.D. from the Wharton School, University of Pennsylvania and has worked at Temple University and at AT&T Bell Laboratories. He is a Co-Principal Investigator of four National Science Foundation grants worth more than a million dollars. The objective of these grants is to develop exceptional instructional materials that bring real-world issues into classrooms and to improve the higher-level cognitive skills of students. These instructional materials have been published and made available as nine textbooks that include multimedia CD-ROM supplements. In addition to his current research and teaching interests, Dr. Sankar has published more than 100 papers in journals, book chapters, and conference proceedings. He has won many awards for research and teaching from the Society for Information Management, NEEDS and John Wiley and Sons, Decision Sciences Institute, American Society for Engineering Education - Southeastern Section, American Society for Mechanical Engineering, Auburn University, and the Project Management Institute. Further information about Dr. Sankar's research and teaching accomplishments could be obtained from the web site: [www.auburn.edu/~sankacs](http://www.auburn.edu/~sankacs).



**John R. (Tony) Cook** has been an Extension 4-H Program Specialist since May 1982. As an Extension 4-H Specialist in Science & Technology Literacy, programs are developed and implemented relating to the mechanical sciences, new technology, and science literacy. It includes support for traditional content areas such as tractor safety, powered equipment, bicycle use & safety, automotive safety, electrical energy applications, energy utilization, safety, computer utilization and others. The work involves the development and support of curriculum for these content areas. Leadership is also provided to delegations of youth that participate in regional and/or national events. Camp/conference programs that relate to the content areas supported in this position are planned and coordinated. Additional responsibilities include assisting county extension agents in planning, organizing, conducting and evaluating Science & Technology and other programs. Further support is provided to the overall 4-H Youth Development Program of Alabama in youth development program development, management and training of extension agents and volunteers and other duties as needed. Additional information regarding Dr. Cook's program accomplishments can be obtained at <http://www.aces.edu/~jacook/>.





## Appendix I

4-H program, Sept. 7, 2002; 9 a.m. – 3 p.m.

### Energy Warriors

Camp Leaders: Don Bryant (Physics), P.K. Raju (Engineering), Chetan S. Sankar (IT)  
Camp Coordinators: Tony Cook (Logistics), Lakshmi Sankar (Curriculum), Michael Gray (Evaluation)  
Camp Helpers: AU Students (Dan, Shiva, Srinivas) and Michael

#### **Camp Objectives:**

- I. Each student will
  - (a) learn about, experience, and use information technologies to explain a science project
  - (b) be motivated to learn more about science, in particular physics
  - (c) experience science learning outside of formal classroom environments
- II. Parents/ coordinators will
  - (a) be stimulated to support their children's science learning endeavors
  - (b) become informed proponents for high-quality science education

#### **Session I**

9 a.m. – Introduction to program: Tony Cook and P.K. Raju  
All participants complete a perceptual questionnaire

Energy Basics: Leader: Don Bryant

- Powerpoint slides introducing the module
- What do you know about energy?
- Tutorial on Physics Warriors: Energy Basics Background material:
  - o Powerpoint slides, Videos explaining potential, kinetic energy
  - o Videos/Examples showing types of energy

Multimedia Basics: Chetan S. Sankar

- Overview of multimedia presentation
- Show how to use a digital camera

10.20 – 10.30 - Break

#### **Session II**

10.30 a.m. – - Review and Instructions for the Science Projects: Don Bryant

10.40 – 11.40 a.m. – Work session: Science Project

- Please ensure that you collect enough data and take sufficient photos for the multimedia presentations.
- Parents/ coordinators could help the student teams in accomplishing the goals of the science project.

1.40 a.m. – Clean up, Return instruments and get ready for lunch.

11.45 a.m. - Lunch break

### **Session III**

12.30 p.m. –Instructions for multimedia presentations project: Daniel Seaton

12.40 – 1.30 – Work session: Multimedia project

- Include photos in presentations, write short notes, include photos/videos from Della CD, put them in Powerpoint and prepare a presentation on the project experience.

1.30 p.m. – Get ready to present

1.40 – 1.45 p.m. - Break

### **Session IV**

1.45 p.m. – Instructions on showcasing and presentation of the projects: Tony Cook and P.K. Raju

1.50 p.m. – Showcasing and presentation of the projects by each team. Each team will have about 5 minutes for the presentation

1.45 – 2.35 p.m. – Presentations and questions and answers

2.35 – 3.00 p.m. – Complete what have I learned about energy and evaluation questionnaire

3.00 p.m. – Camp is complete.



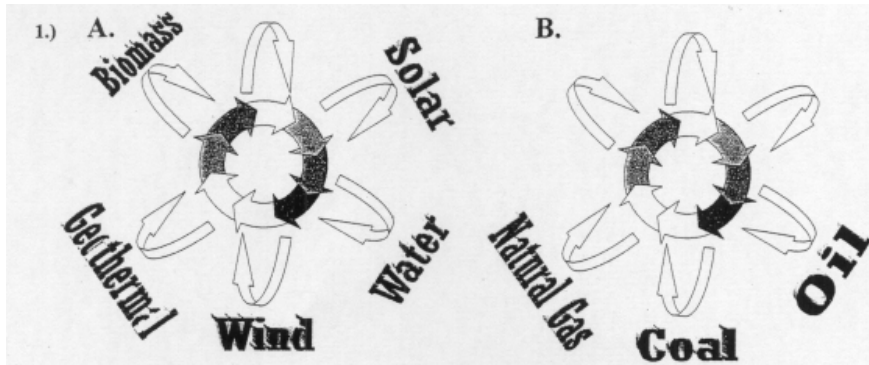
# Appendix II

## MODULE ONE: ENERGY BASICS – “Energy Warrior Boot Camp”

What do you know about energy?

Name \_\_\_\_\_

Please answer the questions to the extent possible. If you don't know the answers, please leave them blank.



Identify by using the appropriate letter:

Nonrenewable energy \_\_\_\_\_ Renewable energy \_\_\_\_\_

2 Match the items on the left with the correct answer from the right. Insert the appropriate letter.

- |                                     |  |
|-------------------------------------|--|
| _____ energy                        | a. the total energy of a system cannot change unless work is done on that system |
| _____ kinetic energy                | b. ability to do work  |
| _____ law of conservation of energy | c. energy of motion  |
| _____ mechanical energy             | d. the sum of kinetic and potential energy                                       |
| _____ potential energy              | e. energy an object has stored   |

3. A \_\_\_\_\_ in potential energy causes an equal increase in kinetic energy.

4. Name three types of energy and provide an example of each.  
(ex. Nuclear energy: atomic bombs)

_____	_____
_____	_____
_____	_____

5. Here on earth we can trace all of our energy back to the \_\_\_\_\_.

**Answer True or False. If it is false, write the correct answer.**

6. T / F A rowboat always has less energy than an ocean liner.
7. T / F We cannot create any new energy, even with a battery or generator.
8. T / F Potential and kinetic energy are synonyms.
9. \_\_\_\_\_ energy is present in a stretched rubber band.
10. When \_\_\_\_\_ gets done, energy gets used.
11. What kind of energy is required to cause things to change states (from solid to liquid, for example)?
12. What is the type of energy in a battery to produce electricity?
13. Name one source of energy used to generate electricity at a big power plant?
14. Give an example of a software that could be used to create a webpage?
15. What does www stand for?

## Appendix III

Your responses to the following items will enable us to evaluate the value of this workshop. There are no right or wrong answers. Please respond to all items and be honest in your responses. **Using the scale below, indicate the extent of your agreement/disagreement with each of the following items by circling 1 to 5.**

	1	2	3	4	5
	Not at all	A little	Kind of	Some	A lot
1. I know _____ about basics of energy.	1	2	3	4	5
2. I know _____ about the different types of energy.	1	2	3	4	5
3. I know what potential energy is.	1	2	3	4	5
4. I know what kinetic energy is.	1	2	3	4	5
5. I know how to construct a web site.	1	2	3	4	5
6. I know how to incorporate a photo in a web site.	1	2	3	4	5
7. I know how electricity is produced in a power plant.	1	2	3	4	5
9. I know what voltage is.	1	2	3	4	5
10. I know what electrolyte is.	1	2	3	4	5
11. I know combination of different materials produces varied amount of electricity.	1	2	3	4	5
12. I can rank the three metals (Fe, Mg, and Zn) according to chemical activity.	1	2	3	4	5
13. I know what atom is.	1	2	3	4	5
14. I understand about conversion of energy from one state to another.	1	2	3	4	5

# Appendix IV

## Module One: Energy Basics – “Energy Warrior Boot Camp” FRUITFUL ENERGY Hands-On Exercise

“Juice” is a slang term sometimes used for electricity. Electrical energy can be generated in several different ways. In this experiment, you will investigate one of these ways: changing chemical energy into electrical. You will use various types of metals to act as the positive and negative “poles” or “electrodes” of a battery and various fruit juices to act as the chemical agent between them, inside the “electrochemical cell.” You will use a voltmeter to measure the voltages produced by the various combinations.

### OBJECTIVES:

- Construct electrochemical cells
- Use a meter to measure and display voltages.
- Record your measurements
- Use your data to determine which combinations meet certain criteria.

### MATERIALS:

- voltmeter
- 2 wire leads with alligator clips
- five types of fruit
- paper towels
- calculator
- pen or pencil
- ruler
- four electrode materials
  - carbon (C) (pencil)
  - zinc (Zn) (short nail)
  - iron (Fe) (long nail)
  - magnesium (Mg) (thin strip)
- data sheet
- highlighter

PROCEDURE (Read all procedures before beginning—ask questions as soon as you have them).

1. Set the voltmeter to read dc voltage, as instructed.
2. Attach the meter’s red test lead to one of the alligator clips on the red wire, and the black meter lead to a clip on the black wire. You will use the free red and black alligator clips to attach to the electrodes in each step. This prevents acid from the fruit juice from corroding the meter’s test leads.
3. Use the combinations of materials and fruits in your data table to make the electrochemical cells. For example, if your data table calls for C and Fe in a lemon, then insert the pencil (carbon) and the long nail (iron) into the lemon 3 cm apart (use 3 cm for all pairs of electrodes you do).

Make sure the electrodes are deep enough into the fruit to contact the juice inside the fruit. Do not let the electrodes touch each other, either outside or inside the fruit. (If your meter reads zero, chances are that this is what has happened.)

4. Connect the test leads to the electrodes in the red-black order shown first on your data table. Start counting off the seconds as soon as you connect both leads. Write the first meter reading in the “first” section of the data table for that particular combination, and write the “last” voltage reading off the meter after you have counted fifteen seconds.

**IMPORTANT:** Place a paper towel under the fruit as you start to use it, to prevent getting juice on the work table.

Do all the reading for one type of fruit first. Then wipe the electrode materials clean with a paper towel before using them in the next type fruit. This will help prevent “contamination” of one type fruit with the juice of another.

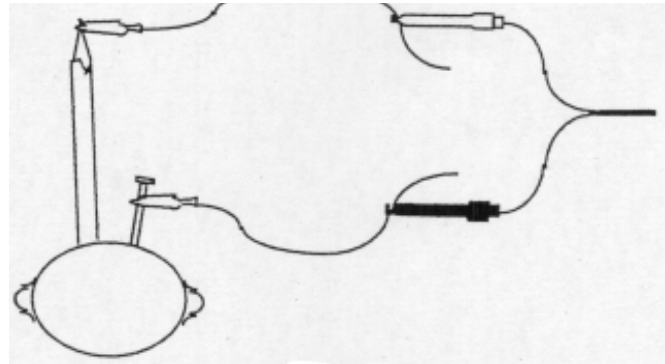
**NOTE:** When using the magnesium strip, it is so flexible that you will need to start the hole for it with a pen or pencil tip before it will go into the fruit. When using the pencil as an electrode, the alligator clip must touch the graphite firmly—not the wooden part of the pencil.

5. Continue until you have filled in all the data table “first” and “last” readings.

### CALCULATIONS:

Use the calculator to determine the averages shown on the data table.

1. In the right-hand columns, find the average “first” and “last” voltage readings for the pair of materials in that row. Then find the average change (delta) from first to last for each one.



2. Across the bottom, do the same averaging for the different fruit types used.

ANALYSIS:

1. When you swapped the red and black leads on the first two types of electrodes, what did you observe happen?

2. Looking at just the "first" voltage readings, highlight the highest and lowest numbers on the data table.

Your highest reading was for which electrode pair? \_\_\_\_\_ and \_\_\_\_\_

Your lowest reading was for which electrode pair? \_\_\_\_\_ and \_\_\_\_\_

3. List the electrode pairs in order, from highest-to-lowest, according to their average "first" voltages. (Do not include any of the negative readings.)

- \_\_\_\_\_ and \_\_\_\_\_
- \_\_\_\_\_ and \_\_\_\_\_
- \_\_\_\_\_ and \_\_\_\_\_
- \_\_\_\_\_ and \_\_\_\_\_
- \_\_\_\_\_ and \_\_\_\_\_
- \_\_\_\_\_ and \_\_\_\_\_

4. List the fruits in order, just as you did the materials in step 3.

- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_

5. List the pairs of electrodes in order, from greatest to least, based on the average change during the 15-second period.

- \_\_\_\_\_ and \_\_\_\_\_
- \_\_\_\_\_ and \_\_\_\_\_
- \_\_\_\_\_ and \_\_\_\_\_
- \_\_\_\_\_ and \_\_\_\_\_
- \_\_\_\_\_ and \_\_\_\_\_
- \_\_\_\_\_ and \_\_\_\_\_

6. Based on your answers above, which type electrode pair would you want to use if you did not know what type fruit you would have, but you wanted the highest possible starting voltage?

\_\_\_\_\_ and \_\_\_\_\_

7. Which type fruit would you want to use if you did not know what type electrodes you would have, but you wanted the highest possible starting voltage? \_\_\_\_\_
8. Which electrode pair would you want to use if you did not know what type fruit you would have, but you wanted the most stable (unchanging) voltage?  
\_\_\_\_\_ and \_\_\_\_\_
9. Which type fruit would you want to use if you did not know what type electrodes you would have, but you wanted the most stable voltage?  
\_\_\_\_\_

**TEAM NAME**

RED	BLACK	LEMON	GRAPEFRUIT	APPLE	BANANA	PEAR	AVG	AVG $\Delta$	NOTES
C	Fe								
Fe	C								
C	Mg								
Mg	C								
C	Zn								
Fe	Mg								
Fe	Zn								
Zn	Mg								
	AVG								
	AVG $\Delta$								

**FRUITFUL ENERGY  
DATA TABLE**

PUT "FIRST" VOLTAGE READINGS IN THEW TOP HALF OF THE BOXES

PUT "LAST" VOLTAGE READINGS IN THEW BOTTOM PART OF THE BOXES